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of Engineers
Fort Worth District

SAN ANTONIO RIVER AND TRIBUTARIES, TEXAS

FOUNDATION REPORT

SAN PEDRO CREEK TUNNEL AND SHAFTS

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DEPARTMENT OF THE ARMY
FORT WORTH DISTRICT, CORPS OF ENGINEERS
FORT WORTH, TEXAS

FOUNDATION REPORT

San Pedro Creek Tunnel and Shafts

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FOUNDATION REPORT
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TABLE OF CONTENTS

TABLE OF CONTENTS (CONT)

PART V: EXCAVATION AND SUPPORT PROCEDURES

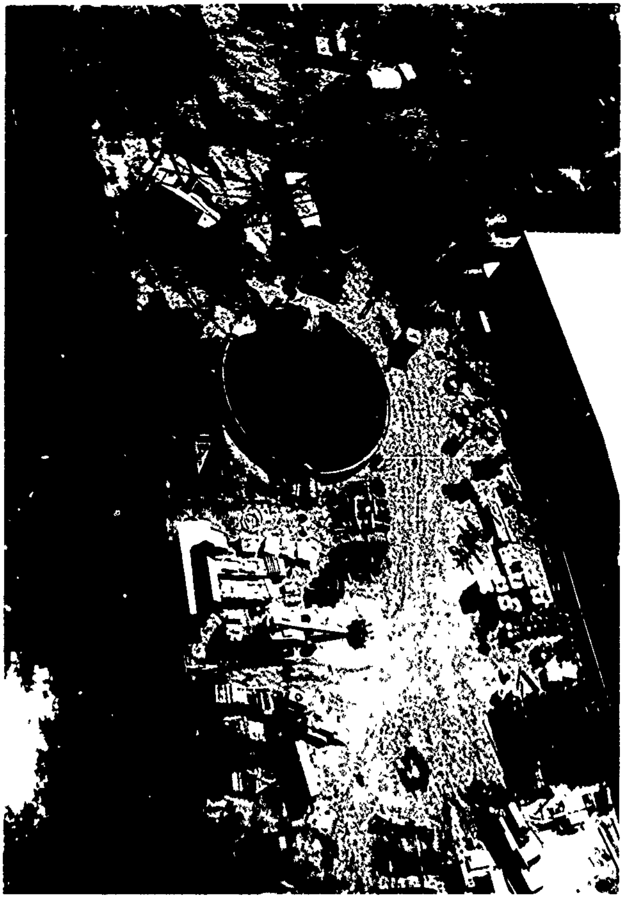
PART VI: CHARACTER OF FOUNDATION OR TUNNELING MEDIUM

PART VII. FOUNDATION TREATMENT

PART IX: GEOTECHNICAL INSTRUMENTATION

TABLE OF CONTENTS (CONT)

SAN PEDRO CREEK INLET SHAFT
Aerial View Southeast



SAN PEDRO CREEK
OUTLET SHAFT
Aerial View
Southwest

PART I

INTRODUCTION

1-01. Location and Description of Project. This project,"The San Antonio River and San Pedro Creek Tunnels, Phase II-Tunnels and Shafts," is part of the broader San Antonio Channel Improvement Project. The latter is a flood control project for the upper San Antonio River and four tributaries--Martinez, Alazan, Apache, and San Pedro Creeks. The subject of this report is a tunnel constructed on San Pedro Creek.

San Pedro Creek Tunnel is the shorter of the two inverted siphon tunnels which have been designed to prevent flooding in downtown San Antonio, Texas. Both tunnels are of the same design and same general dimensions, and have been excavated by the same tunnel boring machine (TBM). Each tunnel will divert flood waters from its respective drainage into an inlet shaft located upstream from the city, and transfer the water beneath the city to an outlet shaft downstream. San Pedro Creek Tunnel extends 5,985 feet from the center of the inlet shaft to the center of the outlet shaft. The longer San Antonio River Tunnel, the subject of a later report, extends 16,225 feet between the centers of its inlet and outlet shafts.

The subject tunnel follows the course of San Pedro Creek in an easterly arc between Interstate Highway 35 on the north and Guadalupe Street on the south. The tunnel slopes downstream at a gradient of .002 from an invert depth of 117 feet (elev. 506) at the inlet to 145 feet (elev. 494) at the outlet. The lining is 12-inch thick precast concrete which gives an inside tunnel diameter of 24 feet 4 inches.

There are seven shafts along San Pedro Creek Tunnel. The inlet shaft is located just south of the intersection of Interstate Highways 35 and 10, and lies between Santa Rosa Street on the west and Camaron Street on the east. It has a cast-in-place concrete liner with a I.D. of 24 feet 4 inches. An 18-foot I.D. cast-in-place concrete maintenance shaft is located approximately 100 feet south of the Travis Street Bridge and just west of Cameron Street. Two 4-foot I.D.steel pipe ventilation shafts are located respectively about 100 feet south of Salinas Street and about 100 feet north of Durango Street. Two 12-inch I.D. steel pipe shafts are located respectively within approximately 150 feet of the inlet shaft and the outlet shaft; these shafts facilitate hydraulic instrumentation measurements once the tunnel is in operation. The outlet shaft is located about 130 feet north of Guadalupe Street just west of San Pedro Creek; it is lined with cast-in-place concrete to an I.D. of 35 feet.

1-02. Construction Authority. Construction of the San Antonio Channel Improvement Project was authorized in the Flood Control Act of 1954 which was approved on September 3, 1954 (Public Law 780, 83rd Congress, 2nd Session).

1-03. Purpose of Report. The objective of this report is to describe the foundation conditions encountered during the construction of the subject tunnel and shafts. It is also intended to be a consolidated record of the foundation related construction operations and an information source for future reference. The report is to be a part of the permanent project engineering and construction record, and will provide background knowledge for evaluation of any future structural problems or further foundation studies.

1-04. Contractor and Contract Supervision. Ohbayashi Corporation of Tokyo, Japan and San Francisco, California was awarded construction of the "San Antonio River and San Pedro Creek Tunnels, Phase II -Tunnels and Shafts" under Contract No. DACW63-87-C-0109 on September 23, 1987. The contract amount was $47,750,000.40. The Notice to Proceed was issued on October 30, 1987, and the contractor acknowledged receipt on November 3, 1987.

Subcontractors to Ohbayashi on the San Pedro Creek Tunnel included Boretec Inc. of Solon, Ohio who selected and re-manufactured a used TBM for the job; Sehulster Company Inc., of Milwaukee, Wisconsin, who manufactured the precast concrete liner segments at a plant established in San Antonio; Woodward-Clyde Consultants of Houston, Texas who were responsible for the specified geotechnical instrumentation program; Cato Electric and Drilling of San Antonio who constructed the concrete soldier piers for the maintenance shaft, Beck Foundation Company of San Antonio who drilled the maintenance, vent, and hydraulic instrumentation shafts, and J-Mar Construction who contracted the muck hauling.

Quality control was provided by the principal contractor, Ohbayashi Corporation. The contractor was required to establish and maintain an effective quality control system consisting of plans, procedures, and organization to insure the contract requirements in materials, equipment, workmanship, fabrication, and construction operations. A quality control system manager (Mr. Lindy White) from within the contractor's organization was required to be at the worksite with responsibility for regulating all quality control matters. A fully qualified staff was required under the system manager with necessary experience and technical training to perform all quality control activities. Records and tests of the contractor's quality control throughout the construction operations were furnished to the Government, as directed by the Contracting Officer. The entire work was subject to inspection and testing by the Government as quality assurance prior to acceptance.

Ohbayashi Corporation's contract supervision was provided by Mr. Kaname Tonoda, General Manager in the San Francisco Office, Mr Carl Linden, on-site Project Sponsor, and Mr. Paul Zick, on-site Project Manager.

The Government's contract administration and quality assurance was provided under Col. William D Brown, the Contracting Officer. Mr Keith M. Allen was the Resident Engineer and Authorized Representative of the Contracting Officer.

1-05 Disputes Review Board. The Disputes Review Board was an advisory body created by mutual agreement between the Government and Ohbayashi Corporation

to assist in the resolution of disputes or claims arising out of the project. The process was a voluntary, expedited and non-judicial, non-binding mediation procedure, whereby an independent three-party Board was presented with Government-Contractor disputes for expert evaluation, recommendations, and possible resolution.

The Board consisted of one member selected by the Government, Mr. Ronald E. Heuer, one member selected by Ohbayashi, Mr. P.E. Sperry, and the final member, Mr. Robert J. Smith, who was selected by the first two members.

The Government and the Contractor were required to mutually agree to submit a dispute to the Disputes Review Board, and the Board's resulting recommendations were non-binding to either party. If the dispute remained unresolved after 30 days following the receipt of the Board's recommendations, the Contractor could submit a request for a Contracting Officer's Decision under the "Disputes" clause of the contract.

This report was prepared by the Resident Geologist, Mr. Roy Crutchfield, during construction of the subject tunnel. The Resident Engineer was Mr. Keith Allen who succeeded Mr. Bob Wortham in November 1988. The Chief of Construction Division was Mr. Shigeru Fujiwara. The Fort Worth District Engineer was Colonel John Schaufelberger succeeded by Colonel William Brown in September 1989.

Consultation and support in preparation of the report was provided by the Fort Worth District Geotechnical Branch, Engineering Division. Mr. Mel Green was Chief of Geotechnical Branch, Mr. Bob Behm was Chief of Engineering Geology Section, and Mr. Harlan Karbs was Chief of the Soils Design Section.

1-06. References.

a. Design Summary Report with Appendices A and B, San Antonio River and San Pedro Creek Tunnels, Phase II -Tunnels and Shafts, Solicitation No. DACW63-87-B-0085, dated May 1987.

b. Design Memorandum No. 5, Part III, Supplement I, Construction Unit 7-3-1, dated November 1985.

c. Geologic Atlas of Texas, San Antonio Sheet, Project Director Virgil E. Barnes, Univ of Texas at Austin, Bureau of Economic Geology, 1983 revised edition.

d. A Revision of Taylor Nomenclature, Upper Cretaceous, Central Texas by Keith Young, Bureau of Economic Geology, Geological Circular 65-3, dated May 1965

e. Ground-Water Geology of Bexar County, Texas by Ted Arnow, Geological Survey Water-Supply Paper 1588, dated 1963.

f. Geologic Map of Bexar County, Texas by A N. Sayre, dated 1932-33 (with modifications by Lang, Brown, Mitchell, and Arnow dated 1959).

g. The Geology of Texas, Volume I, Stratigraphy by Sellards, Adkins, and Plummer. The University of Texas Bulletin No. 3232, dated August 1932.

PART II

FOUNDATION EXPLORATIONS

2-01. Investigation Prior to Construction. Subsurface investigations prior to tunneling consisted of 25 borings drilled in five phases as the channel improvement plan for this reach of San Pedro Creek developed. The borings ranged from 23-foot deep auger holes to 180-foot deep core holes, and provided 3,085.9 linear feet of drilling exploration. Overburden was usually drilled with 6 to 8-inch augers except when undisturbed samples were taken with 6-inch Denison Barrel or 4-inch Shelby Tube. The primary formation was drilled with fishtail bits or 4 to 6-inch core barrels. All of the borings were drilled under supervision of the Corps of Engineers' Fort Worth District Office with either a Corps drill rig and crew or by contract driller with a Corps geologist. All on-site material evaluation, logging, and photographing was performed by a Corps geologist. Electric logs including resistivity, gamma, and caliper were obtained on the deeper borings, however, due to malfunctions of the resistivity equipment, the gamma logs proved most reliable and consistent for strata correlations.

The first five borings were drilled along the tunnel alignment in June 1975 and May 1981 as shallow investigations for flood capacity improvements planned for the San Pedro Creek channel. This plan was replaced by the tunnel project, but the borings provided relevant near-surface information. These first five borings were 8A-223, 6DC-235, 6DC-236, 6DC-237, and 6DC-238 which extended to respective depths of 23.0, 55 3, 52.0, 48.0, and 51.5 feet

In March and May of 1984, the first tunnel alignment, which was a straight course between the present inlet and a planned outlet near Durango Street, was explored with six borings. Boring 6DC-279 at the inlet and Boring 6DC-287 at the outlet obtained undisturbed samples through the overburden with a 6-inch Denison Barrel and took 6-inch continuous core samples through the primary formation. The remaining four borings, 6A4C-280, 6A4C-281, 6A4C-282, and 6A4C-285, were core sampled only below elevation 540, generally from 20 feet above the tunnel crown to 20 feet below the invert. The material above elevation 540 was drilled with rockbits in primary strata and predominantly with augers in overburden. The only exception to this procedure was that Boring 6A4C-285 was drilled with a fishtail bit in the bottom 10 feet

The initial straight alignment was abandoned in mid 1984 in favor of a shorter version of the current alignment which underlies the curved meander of San Pedro Creek The maximum separation of the two alignments was only about 750 feet; therefore, it was decided that the new alignment could be evaluated through electric log correlations between fishtail borings rather than obtaining additional core samples. Consequently, Borings 3F-283, 3F-284, 3F-295, AND 3F-296 were drilled with 8 and 10-inch augers to a depth of about 40 feet followed by 5 7/8-inch fishtail bits to total depths of 180 feet, approximately 20-feet below invert elevation. One additional core boring, 6A4C-286, was drilled about midway along the new alignment. It was augured to a depth of 51.5 feet and then cored with a 5 1/2-inch core barrel

to a depth of 180 feet. All five of these borings were drilled in August and September 1984.

In 1985, the tunnel alignment was extended 1,718 feet downstream to obtain an outlet site which could provide a larger staging area for construction. This was the present outlet site which is just north of Guadalupe Street and adjacent to San Pedro Creek. Therefore, the final alignment was established, and four borings were added in 1985 and 1986 to complete design investigations for the tunnel and shafts. Boring 6DC-302 was drilled at the final outlet shaft location. Overburden for 6DC-302 was augured in the upper 4.5 feet, drilled with 6-inch Denison Barrel from 4.5 feet to 22.5 feet, and augured again from 22.5 feet to just within weathered primary material at the 31.5 depth. The primary formation was then cored with a 6-inch barrel to a depth of 180 feet. Boring 6A4C-303, located midway on the alignment extension, was augured to 23.0 feet and cored with a 4-inch barrel to 180 feet. Boring 6A4C-304, at Nueva Street, was augured to 40.5 feet, fishtailed from 40.5 to 100.0 feet and cored with 5 1/2-inch barrel to the total depth of 165.0 feet. Boring 6A4C-305, at Martin Street, was augured to 40.8 feet, followed by rockbit to a depth of 100 feet, and then 4-inch cored to 165.0 feet.

Finally, five additional borings were drilled at the inlet and outlet sites in April 1986. These were shallow investigations primarily for design of the inlet and outlet surface structures. The borings were 6D4C-306, 6D4C-307, 6D4C-308, 4S4C-314, and 4S4C-315 which had respective depths of 31.0, 28.0, 33.0, 54.5, and 49.0 feet. (Note: Letter designations in boring numbers represent method of drilling and sampling as follows: A - auger, C - core barrel, D - Denison Barrel, F - fishtail bit, S - Shelby Tube. Numbers preceding these letters indicate the diameter of boring. Logs of design borings are in Appendix F.)

2-02. Investigations During Construction. There was no exploratory drilling during construction, although some additional core sampling was required as part of the geotechnical instrumentation program.

Core samples were taken in Borings X-1 and X-2. These borings were drilled for the installation of vertical 6-position extensometers above the tunnel at Stations 143+75 and 158+47 respectively. Core from both borings confirmed that the primary formation at those stations was massive, unfractured, calcareous clay shale. Boring X-1 was augured 12 feet into unweathered shale to a depth of 48 feet, and then NX size (2.155 inches dia) core was taken to the total depth (logs in Appendix G) NX core samples were also taken in 7 borescope observation holes drilled in the tunnel walls at each of the following stations: 143+63, 143+71, 143+79, 143+87, 143+95, 158+39, 158+47, and 158+55. This was a total of 56 borings drilled to an approximate depth of 8 feet. Each group of 7 borings had a 45 degree spacing around the tunnel circumference, starting at 45 degrees from the invert centerline; no boring was drilled in the invert. The material was massive, calcareous clay shale with occasional fracturing, due primarily to stress relief around the tunnel excavation.

PART III

GEOLOGY

3-01. <u>Regional Geology.</u>

a. <u>Physiography.</u> The San Pedro Creek Tunnel is located where the northeast trending Balcones fault zone forms the boundary between two physiographic provinces, the Edwards Plateau to the northwest and the Gulf Coastal Plain to the southeast. The Edwards Plateau is located on the upthrown side of the fault zone with an altitude ranging from about 1,100 to 2,300 feet. It is a rugged and hilly upland dissected by the headwaters of numerous streams. Limestone, which dips slightly to the southeast, has provided the resistant erosional surface of the plateau and caps the remnant hills. Between elevations 1,100 and 600 feet, the Balcones fault zone forms an abrupt transition from the hill country in the northwest to the rolling plains in the southeast. The zone is marked by fault escarpments in places, but lacks topographic expression where formations on both sides of the faults are equally resistant to erosion, such as along the tunnel alignment. The fault blocks are composed predominantly of limestone and shale beds which dip gently southeastward. The Gulf Coastal Plain lies below elevation 600 on the downthrown side of the fault zone. It is a rolling prairie underlain largely by beds of clay and poorly consolidated sand. The regional dip is greater in this province, continuing southeastward toward the Gulf of Mexico.

b. <u>Stratigraphy.</u> The regional stratigraphy consists of Recent to Pliocene aged alluvial deposits underlain by sedimentary formations of the Tertiary to Cretaceous Periods. The alluvial deposits consist of various combinations of gravel, sand, silt, and clay with occasional cobbles and boulders in places. They are predominantly fluviatile floodplain and terrace deposits of which the oldest two have been formally named, the Leona Formation (lower Pleistocene) and the Uvalde Gravel (Pliocene). The underlying Tertiary formations are of the Eocene and Paleocene time epochs. These consist of clay, lignite, sand, and sandstone of the Claiborne, Wilcox, and Midway Groups. Cretaceous formations are contained in the Navarro and Taylor Groups of the Gulf Series and consist mostly of shale, clay shale or claystone, limestone, and sandstone. The Taylor is discussed more fully in succeeding paragraphs as it relates to the project geology.

c. <u>Structure.</u> The regional structure may be divided into three distinctive areas: The nearly flat and relatively undisturbed beds of the Edwards Plateau; the gently dipping but faulted and folded beds of the Balcones-Luling fault zones; and the southeast dipping monocline of the Gulf Coastal Plain. The rock formations strike east-northeast and dip south-southeast throughout the region. The average formation dip in the Edwards Plateau ranges from 10 to 15 feet per mile, but it increases to 150 feet per mile in the coastal monocline. Between these two areas, the formations dip gently, but are faulted downward about 3,000 feet in a distance of about 22 miles.

Regionally, there are two major fault zones, the Balcones fault zone and the Luling fault zone. The Balcones system contains all of the faults within and north of San Antonio, and is separated by a large graben from the Luling system about 25 miles to the east-southeast. (The Mexia fault zone forms the east side of a similar graben to the north in central Texas.) Both fault zones were apparently part of the same tectonic system which was active during the mid to late Tertiary Period. Normal or gravity faults are predominant in both zones, but the Balcones faults are usually downthrown to the east or southeast and the Luling faults are usually downthrown to the west or northwest. Major faults of both zones trend east-northeastward, roughly parallel to the formation strikes. The almost straight traces of these faults suggest nearly vertical fault planes. Shatter zones are common with numerous small step faults occurring within a narrow area. However, large faults also occur and several are known to have displacements in excess of 100 feet. The Balcones faults have the greatest displacements; a fault northwest of San Antonio, near Helotes, has the largest known throw of about 600 feet, and another fault in south San Antonio has a throw of more than 550 feet.

Although faulting is the more prominent structural feature of the region, the faults generally have decreasing displacements toward the ends of their trace, and in places diminish into folds, especially in the softer strata. A major asymmetrical fold, the Culebra Anticline, plunges southwestward several miles west of the tunnel project. It has a core of Austin Chalk and is flanked by mostly Taylor and Navarro formations. Both flanks of the anticline are terminated by faults of the Balcones system.

3-02. Geology of the Tunnel Alignment.

a. Overburden. Overburden along the tunnel alignment consists of fluviatile low terrace deposits, residual clay, and occasional man-made backfill or construction surfacing. The fluviatile deposits are for the most part clay, clayey gravel, and gravelly clay with lesser amounts of silt and sand. Lower gravel beds are largely composed of calcareous concretions formed around chert or limestone pebbles; these are rounded to subrounded, whitish concretions usually ranging from 1 to 2 inches in diameter, although sometimes as large as 3 inches. A water bearing gravelly clay to clayey gravel is often the basal stratum of the overburden, except where the primary formation is directly overlain by residual clay. The residual clay is tan to buff with gray streaking and mottling, soft, and of medium to high plasticity. It is similar to the underlying weathered clay shale except that it lacks distinct bedding structure and induration. In places, isolated pebbles within the clay suggest possible re-working with the overlying alluvium. Being within a city, the natural overburden is frequently overlain by man-made deposits such as concrete, asphalt, and random soil fill, including minor amounts of construction rubble and other refuse

The overburden blanket, or regolith, along the tunnel alignment varies typically in thickness and character Overall thickness increases downstream along the tunnel alignment from 1 0 foot at the inlet shaft to 27 feet at the outlet shaft. Individual strata range in thickness from about 1 to 10 feet Although the fluviatile deposits are relatively well sorted from the finer grained deposits near the surface to the coarser gravel deposits at depth, the

gravel beds generally display a good gradation in the engineering sense that various grain sizes are distributed throughout. Cobbles are present in places but never numerous. Clayey gravel often grades into gravelly clay. The clay may be either fluviatile or residual. Both types of clay may range from lean to fat in plasticity and are variably calcareous. The fluviatile clay may contain gravel, particularly toward the base of the stratum.

b. Primary Formation. The Taylor Formation/Group is the primary and only rock formation encountered throughout the San Pedro Creek Tunnel excavations. Geologic literature often refers to the Taylor as a stratigraphic group containing several formations. Although the formations vary from place to place in composition and name, the Taylor may be generally divided into three stratigraphic units: the Upper Taylor Marl (also called the Marlbrook Marl or Bergstrom Formation), the Pecan Gap Formation, and the Lower Taylor Marl (also called the Sprinkle Formation). Keith Young, May 1965, in referring to these three formations classifies the lithic sequence as: claystone, chalk or marly limestone, and claystone," thereby substituting claystone for the old marl terminology used by Sellards, et al., August 1932. Since "marl" is an old and loosely applied term for unconsolidated or little indurated materials containing 35 to 65% clay and 35 to 65% carbonate (American Geological Institute's Glossary of Geology, 1974), it can apply to the Taylor in composition only. As a geologically consolidated mass of predominantly clay and carbonate minerals, the Taylor is more aptly classified as a calcareous clay shale where fissile, a calcareous claystone where lacking fine lamination, and possibly a marlstone where highly calcareous. Although the Taylor Formation encountered in the tunnel excavations consists of variations and subtle transitions through all three of these similar rock types, we have for simplicity chosen calcareous clay shale as the general project classification of the Taylor rock.

Locally, the Taylor is treated as a formation rather than a group, since only the upper stratigraphic unit is present. However, the formation contains interbedded calcareous or limy layers which may be used as stratigraphic marker beds in electric log correlations. These marker beds have been designated M-1 through M-5, from youngest to oldest. The fifth marker bed, M-5, represents all of the formation below a distinctive 2± foot thick greensand or glauconitic zone. Due to the formation dip to the southeast and the vertical displacement of faulting, the tunnel crosses through four stratigraphic marker beds from the M-1 at the outlet to the M-4 at the inlet, thereby progressing upstream from younger to older beds. This was significant to the tunnel and shaft excavations. Upstream, the formation becomes more limy as it forms a gradational transition toward the underlying Anacacho Limestone and Austin Chalk. X-ray diffraction tests reveal that the stratigraphically lower and older beds tend to be two to three times more limy. The ratio of clay to calcium carbonate is inversely proportional in this material. Thus, the M-1 and M-2 materials are more clayey and lithologically weaker, the M-3 through M-5 materials are typically more limy, better cemented, and more geologically consolidated to give a denser and stronger rock

Although there is only one rock formation encountered by the tunnel construction, its material characteristics are both variable and distinctive.

A rudimentary visual observation can roughly ascertain the variable clay and carbonate (lime) lithology. The darker gray, unctuous, soft to moderately soft material is higher in clay content; the lighter gray, earthy, moderately soft to hard material is higher in calcium carbonate. More exactly, X-ray diffraction indicates that the rock consists of 30 to 45% clay, 15 to 50% carbonates, 10 to 30% quartz, and a trace to 15% of feldspar. The more prevalent of the clay minerals is the expansive montmorillonite with lesser amounts of non-expansive illite and kaolinite, although this is not everywhere the case. Pyrite crystals occur in places, as does calcite and gypsum; the latter two usually form healing minerals along occasional fractures. Marine fossils appear scattered throughout, though more abundant in certain zones. The flat, spirally twisted pelecypod (oyster) "Exogyra" is common. Black carbonaceous specks are found occasionally, and a 0.1-foot thick lense of lignite was encountered at the 99-foot depth during an extensometer installation at Station 158+47. Other than the typical shaly odor, the material often emits a petroleum odor suggesting the possible presence of hydrocarbons and odorless gases. However, the tunnel excavation was continually monitored for explosive hydrocarbon gases and none were detected.

c. Geologic Structure. The Taylor Formation along San Pedro Creek Tunnel consists of about 230 feet of massive and generally undisturbed strata. Boring investigations had nearly 100% core recovery with RQD also approaching 100%. Construction mapping denoted occasional widely scattered fractures and low angle joints, but these are random breaks that hardly disrupt the massive character of the formation. The apparent dips of the joints and fractures is often 1 degree or less with a maximum of 10 degrees; their direction of dip ranges from southeast to northeast. The stratigraphic inclination varies along the alignment from 0 to 2 degrees, with the predominant dip to the southeast. Some stress relief fracturing occurred around the excavation openings, and occasional block fallouts were noted during the construction of the outlet shaft transition and the downstream tunnel section However, the massive character of the formation undoubtedly limited the stress relief effect.

Though the tunnel was excavated in massive rock, the formation is not without structural attributes of the Balcones fault zone. Features of the fault zone are evident in mid-alignment where a high angle fault crosses the apparent flank of a fold dipping to the south-southeast. With respect to the tunnel alignment alone, the fold appears as a faulted monocline. However, with a broader view of the local structure, it could well be that drag flexures were developed on each side of the fault. The strata is essentially horizontal in the upstream third of the tunnel; the mid-tunnel strata dip at 1 to 2 degrees south-southeast; and the beds in the downstream third level out before turning upward to a northerly dip of 7 feet per mile at the outlet It is this slight reversal in the direction of dip that suggests adjoining flexures resultant from local fault block movements. These flexures may be viewed as upward drag on the downthrown fault block and downward drag on the upthrown fault block.

Extensive geologic investigations for both tunnel alignments on this project have updated and enhanced the depiction of the stratigraphic and structural geology of central San Antonio. Rather than the one fault which was formerly mapped through the downtown area, this project has revealed four faults

trending east-northeast across the central city between Brackenridge Park to the north and Roosevelt Park to the south. Rather than a fault contact between the Taylor and Navarro Formations (Groups) being near the Paseo del Rio, it is actually just r -th of Brackenridge School by about 500 feet. This more complete view of the cal geology lends reason to the development of drag flexures along the tunnel alignment rather than monoclinal folding.

The complete relation of the local structure to the San Pedro Creek Tunnel is made more apparent by projecting westward the faults which cross the San Antonio River Tunnel. If these faults are projected westward, a down-to-the-south fault crosses the tunnel in mid-alignment, and another down-to-the-north fault passes south of the outlet. This broader view of the tunnel geology reveals a horst and graben structure with the northern alignment in an upthrown horst block and the southern alignment in a downthrown graben block. Therefore, the upward turning of the strata at the outlet could indicate a slight synclinal flexure in the downstream graben with an adjoining anticlinal flexure in the upstream horst. The slight dip in the otherwise horizontal beds would indicate drag relative to the movement of these fault blocks.

The geologic structure displayed along the tunnel alignment, though characteristic of the Balcones fault zone, does little to disrupt the massive character of the rock formation. The folding is but minor warping of essentially horizontal strata. The mid-alignment fault at Station 171+50 has 32 feet of displacement, but has caused little disturbance to the surrounding rock. In fact, the only evidence that the fault was crossed by the TBM was that the muck changed from soft, dark gray, clayey, M-1 and M-2 material to the harder, light gray, limy muck of the M-3 strata. However, though the faulting and folding along the alignment is relatively unimposing, they are both significant in that they place four of the five identified stratigraphic marker beds within the limits of the tunnel excavation.

d. Formation Weathering. The predominantly tan coloring of weathered Taylor Formation contrasts sharply with the darker, gray unweathered clay shale. The tan coloration is mottled and streaked with gray generally throughout the weathered zone, and rusty stains of oxidized iron occur along some joints and fractures. Though the unweathered formation is massive with few structural breaks, joints and fractures are not uncommon in the weathered zone. It is noteworthy that since there is little water migration through the fractured areas, the top of the weathered zone may be considered the contact between the Taylor aquiclude and the overlying alluvial aquifer. The weathering usually extends through the upper 15 to 20 feet of the formation with an average thickness along the tunnel alignment of 18.5 feet The contact with unweathered formation is generally at 30 to 40 feet below ground surface or at an average depth of 34.5 feet. The weathered material is soft, has medium to often high plasticity, is damp in places, and contains scattered fossils. It is distinguishable from the occasional residual clay deposits by slight induration and distinct bedding structure. Due to this induration and bedding structure the material tends to break in blocky chunks when excavated

e. Ground Water. The Taylor Formation is an impermeable clay-based rock which forms an aquiclude prohibiting the migration of ground water from

both above and below the formation. Ground water in the overlying alluvium is prevented from moving downward, and ground water in the underlying limestones is confined under artesian pressure. The Taylor is a massive tight aquiclude, although there are occasional structural breaks. Where breakage does occur it is usually tight, closed by intrinsic expansive clays, or healed by mineral precipitation. Thus, the impermeable character of the rock is not significantly altered by fractures, joints, or faults. The tunnel excavation was entirely in dry rock with no seepage along structural breaks.

The shaft excavations were also in dry material for the most part. The San Pedro Creek Inlet Shaft was started in unweathered Taylor Formation after the approach channel construction of a previous contract had removed the alluvial overburden and weathered rock; therefore, the inlet shaft was excavated in entirely dry rock. Concrete soldier piers or steel casing was used to seal off any ground water in the alluvial overburden at each of the drilled shafts. The excavation of the San Pedro Creek Outlet Shaft encountered ground water inflow at 200 gpm at the 19-foot depth. Ground water inflow began at the top of a sand stratum that underlay a gravelly clay. The inflow continued at about 200 gpm through 2 to 2.5 feet of the sand and 5 feet of underlying sandy to clayey gravel to the top of the weathered Taylor Formation. This water was removed with sump pumps, and the rest of the excavation was dry.

The main ground-water concern for the tunnel was that the TBM might excavate through an abandoned and unplugged artesian well. The major water source for the region is the Edwards Aquifer, from which the city has a multitude of wells. Occasionally, unknown abandoned wells are found, and there are no assurances that these old well were plugged as required by current regulations. The Edwards lies confined with an artesian pressure beneath the Taylor and other impermeable strata at a depth of about 690 feet, or 550 feet below the tunnel. It has been estimated that an unplugged well from within this aquifer could release as much as 5000 gpm of water into the tunnel at a pressure of 70 psi. As it turned out, an abandoned well was indeed intersected by the tunnel excavation, but it proved to be more of a nuisance than a major problem.

The abandoned well was encountered by the TBM at about 2400 hours on May 16, 1989 at Station 178+49, the location of liner ring number 898. The well had apparently been plugged to some extent when abandoned, but it was producing water at a steady 2 gpm, which proved difficult for the contractor to stop. Probing of the inner casing was obstructed at the 24-foot depth by what was probably a remnant of the old plug. The well consisted of a 4-inch diameter inner casing, a 6-inch diameter outer casing, and an 8-inch diameter borehole located 2 feet east of the tunnel center line. The contractor's well plugging events were as follows:

> May 17, 1989 -- A professional well driller from T C. Johnson Drilling Company (Well Digger License No. 857) was hired by the contractor to plug the well. First a steel cap with a grouting pipe was welded on top of the inner casing, and then grouting began under the direction of the well driller. After pumping 3 cubic feet of 1:1 grout (water/cement by volume) through the steel cap, grout began flowing between the inner and outer casings. After 6 more cubic feet of 1:1 grout was pumped, grout

leakage developed through cracks in the rock within a 2.5-foot radius of the well. The well driller declared the well plugged after a total of 12 cubic feet of 1:1 grout had been pumped at pressures reaching as high as 150 psi. However, clear water continued to flow out of cracks in the surrounding rock. The contractor allowed the grout to set-up for a couple of hours and then resumed tunneling.

May 18, 1989 -- The well was obviously not plugged since about 2 gpm of water was still flowing into the heading invert from beneath the liner segments. Two holes were drilled through liner ring number 898 to reach the well.

The contractor attempted to plug the well in a fashion similar to the previous attempt. The grouting was stopped after 13.5 cubic feet of 1.1 mix was pumped. It was noted that grout was being forced out between the liner segments.

May 19, 1989 -- Water continued to flow into the heading invert. However, the well was by this time beyond reach or observation since it was beneath the TBM trailing gear.

May to September, 1989 -- The holes through liner ring number 898 were backfilled with pea gravel and left open for observation of the well flow. The flow rate continued through this period at about 2 gpm.

September 28 to October 16, 1989 -- A 5.5-foot long by 3-foot wide by 3-foot deep rectangular hole was excavated around the well The water flow continued at about 2 gpm from the annular space between the outer casing and the borehole

October 16, 1989 -- Once again the contractor attempted to plug the well No water was actually flowing out of the well casing which could only be probed to a depth of 15 feet; this was 9 feet higher than the original probe on May 17, and indicated that previous groutings had sealed off the well casings. Since the water was only flowing out of the outer annular space, the upper well casings were backfilled with 1 1 grout. A grout pipe and a flow pressure relief hose were fixed into the annular space; the grout pipe extended 6 feet below the top of the casing, and the pressure relief hose went about 2 feet into the annular space. An unknown amount of 8:1 to 1.1 grout was pumped into the annular space at 10 psi for about 2.5 hours. Grout leaks persisted in cracks in the surrounding rock, even though saw dust was used as lost circulation material and plugs were driven into leak holes It was finally decided to let the grout set-up overnight.

October 17, 1989 -- The well's outer annular space continued to leak at 1 to 2 gpm. Grouting was reinitiated in the annular grout pipe, but was shortly stopped in favor of pouring a heavy grout cap over the well. The 5.5-foot by 3-foot hole surrounding the well was filled with heavy grout with grout pipes placed at previous leak locations for future grouting

October 18, 1989 -- The grout cap had set-up overnight, but had water leaks in a few places. Grouting resumed through the pipes installed in the grout cap. There was a total of 42 cubic feet of 1:1 mix pumped at 93 psi. Some water was noted at joints in the upstream liner segments.

October to December, 1989 -- The grout cap over the well was observed for renewed seepage during this period. The cap became completely dry, and the well was considered plugged.

November 30 and December 1, 1989 -- The upper foot of the grout cap was saw cut and removed. This hole was then backfilled with 6000 psi concrete.

f. Seismicity. The San Antonio area, as most of southern Texas, is in a Seismic Probability Zone 0. This zero zone extends north-south from Dallas to Brownsville and east-west from Beaumont to Del Rio. No earthquake damage has ever been experienced within this zone, nor should any be anticipated in the future. There are no distant threats from earthquakes beyond this zone. Therefore, the tunnel project has no seismic risks.

g. Engineering Characteristics of Overburden. The predominant component of the overburden is medium to high plasticity clay though silt, sand, and gravel also occur. The gravel deposits are often clayey to a variable extent ranging from clayey gravel to gravelly clay. Silt and sand layers are also slightly clayey in places. Though the overburden consists of various gradations from fine to coarse materials, it was possible through thorough investigations to develop one set of overburden design parameters for all of the shaft and surface structures. These parameters are as follows:

1. Moist Unit Weight (γm) = 125 pcf
2. Saturated Unit Weight (γsat) = 130 pcf
3. Shear Strength Assumptions:
   a. Cohesion (c') = 0.1 tsf
   b. Angle of Inner Friction (ϕ') = 20°
4. Allowable Bearing Capacity (qall) = 2.0 tsf
5. Earth Pressure Coefficients:
   a. Ka (active) = 0.5
   b. Ko (at rest) = 0.7
   c. Kp (passive) = 2.0
6. Modulus of Subgrade Reaction
   or Spring Constant (Ks) = 75 pci

h. Engineering Characteristics of Primary Formation. The characteristic of the primary formation which caused the greatest design concern was its capability of exerting relatively large swell pressures on tunnel and shaft linings due to its montmorillinite content. Although the swelling pressure is very low in some of the material and is usually less than 5 tsf, it is known to be as high as 15 tsf in places. Therefore, geotechnical consultants were engaged as advisors during the tunnel and shaft design The swell pressure characteristics and the recommendations of the consultants are discussed in Part IV, Special Design Considerations, Paragraph 4-02

Other engineering characteristics were determined for selected undisturbed samples along the tunnel alignment. In Atterberg tests, the average liquid limit was 50 with a high of 75 and a low of 34; the average plastic limit was 17 with a high of 19 and a low of 14; the plasticity index averaged 33 with a high of 56 and a low of 20. The moisture content ranged from 6% to 15.8% with an average of 10.5%. Specific gravity was about 2.70. Dry density ranged from 116 pcf to 140 pcf with an average of 129 pcf. Unconfined compressive strengths near the tunnel depth varied from 25.6 tsf to 132.8 tsf, averaging 71.4 tsf. The soil modulus near tunnel depth ranged from 2.2 X 10^4 psi to 19.8 X 10^4 psi, with an average of 9.1 X 10^4 psi.

A set of design parameters were developed for both the weathered and unweathered primary formation, noting characteristic changes with depth. These parameters are as follows:

Weathered Shale (undisturbed)

1. Moist Unit Weight (γm) = 125 pcf
2. Saturated Unit Weight (γsat) = 130 pcf
3. Shear Strength Assumptions:
    a. Cohesion (c') = 0.1 tsf
    b. Angle of Inner Friction (ϕ') = 25°
4. Allowable Bearing Capacity (qall) = 3.0 tsf
5. Earth Pressure Coefficients:
    a. Ka (active) = 0.4
    b. Ko (at rest) = 0.9
    c. Kp (passive) = 2.5
6. Modulus of Subgrade Reaction or Spring Constant (Ks) = 250 pci

Unweathered Shale (undisturbed)

1. Moist Unit Weight (γm) = 135 pcf
2. Saturated Unit Weight (γsat) = 140 pcf
3. Shear Strength Assumptions:
    a. Cohesion (c') = 0.1 tsf to 0.5 tsf @ tunnel depth
    b. Angle of Inner Friction (ϕ') = 35° to 45° @ tunnel depth
4. Allowable Bearing Capacity (qall) = 6.0 tsf

(Note: The allowable bearing capacity for the unweathered shale actually exceeds 6.0 tsf at tunnel depth, but with no effect on structural design.)

PART IV

SPECIAL DESIGN CONSIDERATIONS

4-01. Construction Method. The tunnel concept for flood diversion beneath the city was adopted rather than surface channel modifications to avoid construction impacts to the downtown area. Significant costs and liabilities would ensue from surface construction along the drainage channel due to limited access, potential damage to structures, bridge replacements, traffic congestion, business restrictions, and other city related problems. However, though convenient from a construction standpoint, the tunnel method along San Pedro Creek was necessarily incorporated with the flood control tunnel planned for the downtown reaches of the San Antonio River. Because of the high cost of a tunnel boring machine (TBM) and initial mobilization expenses, the cost per foot of tunnel is substantially decreased as the length of tunneling increases. The 5,985-foot long San Pedro Creek Tunnel would hardly have been cost effective without the additional 16,200-foot length of the San Antonio River Tunnel. Therefore, without the added length of the San Antonio River Tunnel, the San Pedro Creek project would have been restricted to surface channel improvements, or less expedient but lower cost conventional methods of tunneling.

A fully shielded, mechanical tunnel excavating machine was specified for the contract which included both the San Pedro Creek Tunnel and the San Antonio River Tunnel. The contractor was given the choice of using a full-face tunnel boring machine (which was chosen), a boom header machine, or a roadheader machine; the latter two would have been allowed only if fully shielded and equipped with an excavation guide ring.

The contractor was also given the option of following the excavating machine with cast-in-place concrete liner or precast concrete segmental liner, provided that the installation of either left no ground unsupported behind the shield. The precast segmental liner was the selected method, providing both initial and final support. The contractor was also given the flexibility to design the liner erection and support method, although the contract plans presented a method using longitudinal needle beams and steel ribs. The method of liner erection was specified to provide "positive structural support" to prevent deviation from circularity of the segmental rings and to prevent settlement of the rings into the invert void as the segments left the back of the tail shield. The contractor's designed method was to set invert segments on a bed of pea gravel, use interlocking dowels between segment rings, support segments at springline with wood blocking, and finally blow pea gravel around the entire ring to provide positive structural support. The lower portion of the tail shield behind the grippers was removed to facilitate this operation.

The specified shaft excavations also allowed the contractor flexibility in selecting a preferred method of construction. The inlet, outlet, and maintenance shafts could be excavated by mechanical ripping, controlled blasting, or a combination of these techniques. Actually, the maintenance shaft was excavated by rotary drilling, and no blasting was used on any

portion of the San Pedro Creek project. The small diameter shafts for ventilation and hydraulic instrumentation were specified for drilling with the option of proceeding downward from the surface or upward from the tunnel (raise drilling). These were drilled downward from the ground surface.

4-02. Swell Pressures. The swelling potential of the primary formation was a major design consideration, especially in the determination of strength requirements for the tunnel and shaft liners. Laboratory testing during design investigations indicated that the material was capable of exerting expansion pressures considerably larger than the overburden pressure. Swell pressures of as much as 12.8 tsf were recorded with a maximum overburden pressure of 8.8 tsf at a depth of 135.3 feet. However, it was questionable as to whether the tunnel and shaft liners would actually have to withstand field pressures as great as those indicated by the laboratory constrained testing. In support of this questioning was previous swell testing by Dr. Tor Brekke on Taylor material from the Austin Crosstown Wastewater Interceptor. Dr. Brekke's tests had shown that permitting the material to experience a volume increase of 2 % reduced the swelling pressures by roughly 50%. On the other hand, the montmorillonite content of the Taylor in Austin varied somewhat from that of the Taylor in San Antonio tunnels. Therefore Dr. Ralph Peck was engaged by the government as a consultant in resolving these questions and other geotechnical issues throughout the tunnels project.

At the recommendation of Dr. Peck, Dr. G. Mesri of the University of Illinois was enlisted to do further testing and evaluation of the Taylor swell properties from samples taken along the tunnel alignments. Based on the previous design tests, field observations, and Dr. Mesri's tests, both consultants recommended that the tunnel and shaft liners should be designed to withstand swell pressures of 5 tsf.

The reasoning of the consultants was that the potentially high expansion pressures indicated by laboratory testing would be largely dissipated as the swelling material expanded into space provided by stress relief fissures that inevitably develop around underground excavations. In Dr. Peck's words, "...the stress release associated with excavating the tunnel of 20-feet (26.9 feet) diameter would undoubtedly be sufficient to cause the opening of fissures around the tunnel to an extent that the ultimate swelling pressures would be reduced to the design value (5 tsf). These fissures would be developed by the time the tailpiece of the shield would expose the shale." Likewise, Dr. Mesri concluded that laboratory pressures would not develop in reality against the tunnel liner because the magnitude of shale rebound after excavation would open fissures around the tunnel periphery. He also expected swell pressure dissipation due to expansion into the tunnel's annular space about the lining, due to flexibility of the lining itself, and due to partial swelling of the material before the lining could be installed Dr. Mesri's tests produced swelling pressures ranging from 0.2 tsf to as high as 15 tsf, although more than 2/3 of the results were less than 5 tsf. (This broad range is indicative of the variable montmorillonite content throughout the formation.) However, similar to Dr. Brekke's findings, he found that to allow additional swelling in a laboratory specimen above the initial void ratio, corresponding to 0.35% axial strain, reduced the swelling pressure from 8 tsf

to 4.5 tsf. Therefore, it was concluded that the inherent field conditions in tunneling would reduce the actual swell pressures on the lining.

Although Dr. Mesri estimates from calculations of the time-rate of swelling that the total design pressure will require decades to develop, experience within the San Antonio area suggests that a substantial amount of the swelling can be expected within 5 years. Based on local experience, it is anticipated that most of the 5 tsf may be realized upon the tunnel and shaft liners within 5 to 10 years after construction. Expansion is usually negligible beyond 12 to 15 years after the moisture environment is changed.

4-03. Heave Potential. Another design consideration was vertical uplift or heave due to differential expansion of the material surrounding the shafts. Since the percentage of expansive montmorillonite varies within the primary formation, the amount of swelling can vary throughout the shafts. Also, moisture variations can affect the rate of swelling from place to place. Particularly, the upper weathered formation is likely to swell more rapidly than the unweathered material at lower depths Therefore, to deal with possible vertical displacements or tensile forces developed by these conditions, the designers recommended that the shafts be constructed with expansion joints, tensile steel, and/or a bond breaker between the permanent and temporary liners.

A shaft bond breaker was specified for the Phase II tunnel contract. (An expansion joint was included in the surface structure design to be constructed under a later Phase III contract.) The specified bond breaker was a geotextile material which was to be installed over the initial support. However, a contract modification provided a substitute for the geotextile which consisted of an asphalt fiber board, Sealtight Dummy Joint, produced by W.R. Meadows, Inc of Fort Worth, Texas.

PART V

EXCAVATION AND SUPPORT PROCEDURES

5-01. General. The contract required that the San Pedro Creek Tunnel and Shafts be completed first, although the San Antonio River Tunnel and Shafts could be started concurrently. There was no differentiation for payment in types of material excavated such as rock or common excavation; payment for shaft excavation was lump sum for each shaft, and payment for tunnel excavation and lining was by the linear foot. San Pedro Creek Tunnel and Shafts involved payment for 5,842.86 linear feet of tunnel excavation, a like amount of precast segmental liner, and lump sum for each of 7 shafts.

Most of the tunnel and shaft excavations closely followed the lines and grades indicated in the plans and specifications. The specified tolerances for the tunnel excavation allowed an alignment departure of ±12 inches, a grade departure of ±3 inches, and a rate of return to alignment or grade not greater than 3 inches per 100 feet. The contract required that the vertical and horizontal tunnel alignment be controlled by laser beam instrument. Although numerous line and grade adjustments were required in controlling the TBM, particularly in negotiating the curve sections, the overall results were quite accurate; the tunnel hole-through at the inlet shaft was little more than an inch northeast of the alignment. No variations were allowed in the thickness of the tunnel lining. The precast segmental liner was allowed a variation of 0.5% from the inside dimension, an out of roundness of ±3/4-inch in diameter, and abrupt irregularities at segment joints not in excess of 1/4-inch. The shaft excavations were allowed 0.5% of the depth in out-of-plumbness or 10% of the finished inside diameter for circular shafts, whichever would be less. Variation from the excavated diameter of circular shafts could not exceed 0 to plus 6 inches. Shaft linings were allowed a variation in thickness of minus 2.5% or 1/4 inch, whichever was greater. The inside dimensions of shaft linings were given a tolerance of 0.5%.

In addition to establishing the lines, grades, and dimensions for the tunnel and shafts, the plans and specifications provided a guideline for implementing the construction. However, the Contractor had the option of submitting for approval his own design proposals for excavation and support. When approved by the Contracting Officer, the Contractor's design and procedures became the de facto specifications in their applicable areas of construction. Each area of construction and the procedures used will be described in the following paragraphs.

5-02. Excavation Equipment.

a. Shaft Excavation Equipment. Two types of equipment were used for the shaft excavations. Mechanical ripping equipment was used in the inlet and outlet shafts, drilling equipment was used in the maintenance, vent, and hydraulic instrumentation shafts. In the inlet and outlet shafts the downward vertical excavation was accomplished by backhoe, but a roadheader was used for outward extensions of the shaft walls and for undercutting the horizontal

transition toward the tunnel. The harder limy-layers in the inlet shaft were broken through by using a hydraulic ram attached to a backhoe. The other five shafts were rotary drilled with a 45 ton Northwest 5045 crane rig. The following is a list of the actual equipment used during the shaft excavations:

Excavation and Mucking

JD 490 Backhoe	TB-45 Excavator
Cat 235 Backhoe	Mitsui Road Header
Cat 205 Backhoe	Cat Loaders 988, 966, 950, 931, 920
Yamashi Backhoe	JD 455 Loader
Mitsubishi Backhoe	Case Bobcat Loader
Yutani Backhoe	Cat IT-28
Takeuchi TB-45 (with hydraulic ram)	630 Rocker (mine mucker)

Cranes

Manitowoc	4600
Northwest	5045
Manitowoc	3900
American	165 ton
Linkbelt	100 ton
P&H	90 ton
Grove	35 ton
Linkbelt	20 ton
Gallion	18 ton
Clark	15 ton
Drott Deck Crane	

b. Tunnel Boring Machine (TBM) The entire tunnel was excavated with a modified Robbins Model 243-217 tunnel boring machine. The machine had been originally designed for hard rock tunneling, and had been previously used to excavate the Kercknoff 2 Tunnel in the Sierra Nevadas near Fresno, California. Ohbayashi engaged Boretec, Inc. of Solon, Ohio to renovate and modify the machine for the soft rock tunneling in San Antonio.

The TBM was converted from an open-faced hard rock machine to a fully closed soft rock machine with articulating shield. A new main beam was installed to shorten the machine and to help moderate the machine weight. The front support shoe was tripled in length to better distribute the machine weight which increased from 380 tons in the original machine to 550 tons with the Boretec modifications. The cutterhead was enlarged from a diameter of 24 feet-1 inch to 26 feet-11 inches, this gave a tunnel annular space behind the liner of 3.5 inches. The main bearing was replaced providing an increase in cutterhead thrust capacity from 1,166 tons to 1,547 tons The side-gripper shoes were enlarged to 56 inches by 138 inches for a better dispersing of forces exerted on the tunnel sides. As an auxiliary propulsion system, 12 thrust cylinders were added with thruster shoes for pushing off of the liner segments; these thrusters could also be used to hold the precast segments during the liner erection. A ring-type segmental liner erector was added within the back of the tail shield. The back 57 inches of the lower

120° section of the tail shield was cut away to allow the placement of the invert segment on a bed of pea gravel.

Although a complete description of the TBM would be too voluminous for this report, there are several additional features which should be noted. When fully operational in the San Pedro Creek Tunnel, the TBM and it's trailing gear was 274 feet long; the length from cutterhead to end of tail shield was 38 feet. The cutterhead contained 57 disc cutters of 15.5-inch diameter. The outermost 7 discs were the gauge cutters which determined the final sizing of the tunnel bore. The outer perimeter of the cutterhead contained 12 bucket scoops which collected the muck and dropped it into the conveyor system within the cutterhead support. The drive torque for the cutterhead assembly was provided by 10 single-speed, 3-phase, AC electric motors producing 200 HP (149 KW)each. These motors rotated the cutterhead clockwise, in an upstream view, at 5.75 RPM. The four main propulsion cylinders, hydraulic jacks, generated horizontal thrusts at 7.5 degrees outward from the tunnel's longitudinal axis resulting in a forward machine thrust and a side thrust on the gripper pads. This system could generate a total thrust force of 2.64 X 10^6 lbs.

Two methods of TBM propulsion were provided since it was anticipated that some of the ground would be too soft, or weak, to withstand the thrust and shear forces exerted through the side grippers. In the stronger, stable ground the four main propulsion cylinders could propel the machine by pushing the side grippers against the tunnel wall. This method does not interfere with preparations for segmental liner erection in the invert area at the back of the tail shield. In ground too weak to withstand propulsion through the side grippers, the machine could be propelled by 12 auxiliary jacks shoving against the segmental liner. However, the shove jacks in this method obstruct the working area at the back of the tail shield.

5-03. Precast Tunnel Liner. The tunnel liner, which also provided the initial support, consisted of precast concrete segments installed within the protective covering of the TBM tail shield. There were 6 segments in each complete ring of liner, forming an inside diameter of 24 feet-4 inches. Each segment was 4 feet wide by 1 foot thick, weighed 8800 pounds, and extended 13.78 feet along a 60 degree arc on the outside of the liner. The bottom 3 segments were id(ical in shape. The top 3 segments were skewed 7 degrees off longitudinal at the two upper joints to accommodate a trapezoidal "key" segment in the crown. The segments were cast of 6000 psi reinforced concrete, and contained two 2-inch diameter grout holes positioned 4.0-feet lengthwise to each side of the center These grout holes were also used for erector handling and for injecting pea gravel into the annular space.

Two types of joints were formed by the segment rings. Circumferential joints divided the rings at 4-foot intervals along the tunnel alignment. Longitudinal or radial joints were formed where the segments joined at each 60° arc of the ring. These longitudinal joints were a tongue and groove type designed by the contractor rather than the specified knuckle type. All of the joints contained a 3/4-inch deep by 1/4-inch wide groove on the inside liner surface for sealant application The sealant used by the contractor was Sikaflex-1A rather than the specified Hornseal.

The segment rings were aligned and locked together at the circumferential joints with "fast-lock dowels" patented by the segment manufacturer, Sehulster Company, Inc.. These dowels were intended to prevent joint spreading and to make the segment rings free-standing. Each circumferential joint contained 18 equally spaced dowels, 3 per segment.

The segmental liner was installed with a circular erector arm at the back of the tail shield. The erector picked each segment up at the invert and rotated it to its proper position within the ring. As the TBM excavated forward, exposing 4 feet of invert rock in the cut away section of the tail shield, a 3-inch thick piece of flexible styrofoam was set on the invert about 3 feet-9 inches in front of the previous ring. Normally, a bed of pea gravel was placed and graded behind the styrofoam barrier in preparation for the invert segment. At times, however, when the tunnel bore was too high, the invert rock was excavated to grade-cut with pneumatic spades, and no pea gravel was required. The invert segment would then be placed with the erector and pushed onto the dowels of the previous ring by the auxiliary propel jacks. This was followed by the placement of each of the two lower rib segments , which were backed by the styrofoam barrier and supported by wood blocking at springline. The upper two rib segments would then by placed, followed by the installation of the key segment in the crown. No styrofoam barrier was placed above springline. After the full ring was erected, pea gravel was blown over and around the back of the segments or through the grout holes. The pea gravel was intended to provide the primary positive structural support. However, final stabilization of the liner was provided with backpack grouting after the trailing gear had cleared the segments. Complete grouting of the full annular space was generally achieved at about 200 to 250 feet behind the trailing gear (500 feet from heading), although this fluctuated considerably.

5-04. <u>Foundation Preparation.</u> The contract requirements for foundation preparation were specified for the most part under technical provisions for placing cast-in-place structural concrete. Of course this did not apply in the tunnel because precast concrete segments were installed immediately behind the TBM tail shield, rather than lining the tunnel with cast-in-place concrete. Neither did it specifically apply to the large diameter shafts (outlet, inlet, and maintenance shafts) because the rock was initially supported with shotcrete long before the structural concrete was placed. Nevertheless, the specifications state that, "Shale or clay shale surfaces upon which concrete is to be placed shall be clean, free from oil, standing or running water, ice, mud, drummy rock, coatings, debris, and loose semi-detached or unsound fragments."

Actually, these conditions were generally met before shotcrete applications, largely due to practical workmanship The excavation and support procedures in the large diameter shafts consisted of shotcrete applications after every 5 to 8 feet of vertical excavation This procedure prevented long term exposure and corresponding deterioration of the rock. The rock was massive and excavated very smoothly, especially with the roadheader, therefore, there were normally no loose blocks or drummy areas in the foundation. Occasional loose fragments were scaled away from the shaft walls before shotcreting. Since it was imperative to provide full contact between the initial support and the

surrounding rock, all over-excavations were fully backfilled with shotcrete as required by the specifications.

The specifications also required that the excavated surfaces of the shafts be protected immediately upon exposure with a polyvinyl acetate emulsion resin containing at least 60(±1)% total solids by weight. Some effort was necessary in enforcing this requirement as well as assuring beneficial applications. Aerospray 70 (or an approved equal product) produced by American Cyanamid Company was specified, but no water dilution mixture was stipulated. The only application requirements were given under the specification section on preparation for cast-in-place concrete placements. An "expert" with the supplier reportedly recommended a sealer to water ratio of 1:20 with an application rate of 1/4 gallon per square yard. However, this mixture appeared too watery with inadequate results, and the contractor eventually increased the ration to 1:10. Where the material was more limy and less susceptible to air slaking the contractor was allowed to omit the resin application if shotcreting was conducted expeditiously.

5-05. Outlet Shaft Excavation. The outlet shaft was excavated and supported according to the contractor's approved design submittals. The 150-foot deep shaft is boot-shaped consisting of an initial vertical section, an intermediate upstream undercut, and finally a tapering 60-foot lateral transition to the tunnel. The entire shaft was excavated by backhoe and roadheader with no blasting required, although the specifications provided for that option. The backhoe was generally used in the vertical excavations whereas the roadheader was used for undercutting or lateral excavations. The initial support was designed by the contractor for a specified rock pressure of 5 kips.

The excavation began with the construction of a collar in the upper 12 feet of the shaft. This upper portion was excavated to a 51-foot surface diameter tapering downward to a 48-foot diameter at the 12-foot depth. As this initial hole was dug, the collar structure consisting of four W12 X 58 steel rings and wood lagging was preassembled on the ground surface. The rings were held 3 feet apart by the vertically placed lagging to form a 12-foot high, open-ended wooden barrel with a 43-foot inside diameter. The collar structure was then placed within the completed hole, and the annular space was backfilled with concrete.

The next 57 feet of shaft, from the bottom of the collar at elevation 569.56, was excavated to a diameter of 42 feet 4 inches, and was variously supported with steel rings, wood lagging, shotcrete, and wire mesh. W8 X 48 steel rings were installed on 4-foot centers through the overburden and weathered clay shale to the 40-foot depth Generally, a 5-inch thickness of 3500 psi shotcrete was applied between the steel rings except where a groundwater inflow of 200 gpm was encountered in the alluvial aquifer lying between elevations 620 and 612 Wood lagging was installed between the rings located at elevations 619, 615, 611, and 607; grouting was then conducted behind the lagging to seal off the ground water Below the 40-foot depth no steel rings were used, but the shotcrete increased to a thickness of 8-inches with the reinforcement of two layers of 6 X 6 - W6 X W6 welded wire fabric.

A single W8x48 steel ring was installed at elevation 569.56 just before the shaft excavation began to widen and undercut upstream toward the tunnel portal. As the shaft was progressively widened with depth, its cross section in plan view became increasingly egg shaped. In plan view, the downstream half of the shaft remained circular whereas the upstream portion elongated to form an elliptical curve. In longitudinal cross sections, this intermediate undercutting between the vertical shaft and the horizontal transition had the shape of an elbow flexure, and thus was called the shaft elbow. The elbow curvature continued to the crown elevation of the transition, 532.59, or a depth of 107 feet. Below this depth the shaft was excavated vertically to invert with a continuous longitudinal diameter of 70 feet 11 inches and a continuous transverse diameter of 49 feet 6 inches.

The initial support below elevation 569.56 consisted of a 12-inch thickness of 3500 psi shotcrete reinforced with two layers of 4 X 4 - W4.7 X W4.7 welded wire fabric. Also, 18 to 21-foot long rock anchors were installed generally on 4 to 5-foot centers and predominantly in the upstream elongated portion of the shaft. These anchors were 1.25-inch diameter, No. 10 Dywidag threadbars cement grouted into 5-inch diameter holes. They were the primary support where the radius of curvature exceeded 30 feet, or where the excavation had no curvature.

The lateral transition excavation extended 60 feet upstream from the vertical shaft at Station 141+98.14 to the tunnel portal at Station 142+58.14. The transition crown and invert elevations at Station 141+98.14 were 532.59 and 490.34, respectively. The transition crown and invert elevations at Station 142+58.14 were 522.05 and 490.46, respectively. Thus, the diameter of the transition tapered from approximately 42 feet at the shaft to about 32 feet at the tunnel portal.

The transition was excavated in four benches in conjunction with the lower 42 feet of vertical shaft excavation. Each of the approximately 10 to 8-foot high benches were cut when the vertical shaft had been excavated to the bottom of that respective level. After the full 60-foot length of the transition was excavated and supported for a particular bench, the vertical shaft was taken down another 10 feet to the bottom of the next bench, and so on to invert.

The transition excavation was supported with W10 X 49 steel ribs and 12 inches of 3500 psi shotcrete. Wood blocking was used only in places to insure that the ribs were making full contact with the surrounding ground; all other gaps between the ribs and the ground were filled with shotcrete. There were 16 of the steel ribs labelled A through P with Rib A set in the first 1 5 feet of the transition, Ribs B and C set on 3-foot centers, and the remaining ribs set on 4-foot centers.

The shaft collar was set between elevation 638.8 and 626 8 on January 29, 1988. Thereafter, the excavation proceeded in 3 to 8-foot vertical tiers, and reached the bottom elevation of 488.0 on August 8, 1988. The lateral transition excavation was completed 4 days later on August 12, 1988.

5-06 Inlet Shaft Excavation. The inlet shaft excavation followed lines and grades similar to those presented in the contract drawings except that

adjustments were made to allow for a 4-inch enlargement of the final inside diameter. The inside diameter of both the inlet shaft and the tunnel were changed from 24 feet to 24 feet 4 inches. The shaft was excavated by backhoe in 4 to 9-foot deep tiers. A hydraulic ram was attached to the backhoe when necessary to break through layers of harder limy clay shale. The primary support was according to the contractor's approved design which allowed for a specified rock pressure of 5 kips.

The first work required at the inlet shaft site was to dewater the approach channel. The inlet shaft was the only large shaft constructed within the actual channel of San Pedro Creek. A concrete approach channel had already been constructed under a previous contract, and was filled with water to a depth of about 15 feet. To dewater the work site, the water was pumped out of the approach channel; a back-flow dike was built downstream from the site; an upstream dam was constructed of steel beams placed across the piers of the Quincy Street Bridge; and water was bypassed from the Quincy Street dam to the back-flow dike through a 30-inch diameter steel culvert. Also, a sump and large trash pump were installed within the dewatered approach channel to remove water from leaks or overflows.

The previous approach channel construction had removed the overburden and weathered clay shale at the site. Therefore, the contractor had only to remove the rip rap, channel concrete, and a few inches of material to begin the shaft excavation in massive unweathered clay shale.

The upper portion of the shaft excavation was in the shape of an equilateral rhombus, but was nearly square with a width of 31 feet 2 inches. It extended to a depth of 21 feet from elevation 623 to 602. The initial support was 3 inches of shotcrete designed mostly to prevent desiccation and air-slaking of the clay shale. Additional support was provided by 24 rock anchors installed on 5-foot centers at each of two elevations, 617 and 612. These anchors were 8-feet long, 3/4-inch diameter, and fully resin grouted.

After the upper shaft was excavated to elevation 602, a 24-foot high by 52-foot diameter circular water protection cell was constructed around the work area The cell was erected to prevent flooding until a temporary concrete surface structure could be built over the shaft. The cell resembled a large, open-ended, wooden barrel similar to the structure constructed for the collar at the outlet shaft. However, this barrel structure was set on the ground surface around the excavation. The cell was constructed of 5 steel rings held apart by 6-foot long wooden lagging placed lengthwise between the rings The steel rings were W12 X 58, and the wooden lagging was actually 6-inch by 8-inch railroad ties. The outside of the cell was overlain with a layer of visqueen to help make it water tight. The base was anchored into the ground by No 11 rebar dowels driven through 24 selectively spaced holes in the bottom steel ring. The base was then shotcreted on both sides. The cell leaked during approach channel flooding, but not profusely

The upper 21 feet of excavation provided the foundation for the temporary concrete surface structure. The structure began within the shaft at elevation 603.43, and had the same rhombus shape as the excavation. The entire structure was constructed of reinforced concrete, which included a 3 0-foot

wide by 3.5-foot deep collar at the ground surface. The structure extended 33 feet above the creek channel to elevation 656, slightly above the 100-year flood level of 655.2.

The shaft excavation gradually changed from the rhombus shape at elevation 603.43 to circular at elevation 578.0. Thus, the radius of curvature at the corners changed from zero at elevation 603.43 to 12 feet 2 inches at elevation 578.0. This portion of the excavation was also supported with shotcrete and rock anchors. The shotcrete design was a 5-inch thickness of 3500 psi shotcrete reinforced with 6 X 6-W2.9 X W2.9 welded wire fabric. The rock anchors were designed as additional support for the straight or uncurved sides of the shaft; this gave progressively fewer rock anchors with depth as the shaft became more circular. The anchors were installed across straight wall sections on 5-foot centers and in 5-foot tiers with depth. The number of rock anchors installed at each respective elevation were 20 at 601, 16 at 596, 12 at 591, 8 at 586, and 4 at 581. These anchors were 18-foot long, 1.25-inch diameter, No. 10 Dywidag threadbars cement grouted into 5-inch diameter holes.

The excavation between elevation 578.0 and the shaft elbow at elevation 553.9 was a vertical circular section supported by 5 inches of 3500 psi shotcrete reinforced with one layer of 6 X 6-W2.9 X W2.9 welded wire fabric. No rock anchors were required in this section.

Below elevation 553.9 the elbow curvature of the shaft began to undercut toward the tunnel portal. Unlike the outlet shaft, this shaft was the same diameter as the tunnel, and required no transitional tapering between the elbow section and the tunnel portal. The excavation below elevation 553.9 was initially planned to stop at elevation 517, about a foot below tunnel springline, and thereby allow the TBM to excavate the remainder to invert when it holed-through into the shaft. However, the shaft excavation continued to elevation 508, which left only 3.6 feet for the TBM to excavate to invert elevation 504.4.

The elbow excavation was supported with shotcrete and rock anchors. The shotcrete was 8 inches thick and reinforced with one layer of 4 X 4-W4.7 X W4 7 welded wire fabric. In the downstream section of the shaft, where the radius of curvature exceeded 15 feet, rock anchors were used for added support. These were 15-foot long, 1.25-inch diameter, No 10 Dywidag threadbars cement grouted into 5-inch diameter holes. The anchors were generally spaced on 4 to 5-foot centers and perpendicular to the shotcreted wall However, in the crown, or "brow," of the elbow curvature they were inclined upward at 37°.

Excavation of the San Pedro Creek Inlet Shaft began at elevation 623 in the creek channel on October 10, 1988. The rhombus shaped upper portion of the excavation was completed to elevation 602 on October 18, 1988. The temporary concrete surface structure was then constructed after which the shaft excavation resumed on January 6, 1989. The next section, which was a transition from rhombus to circular shape, was completed at elevation 578 on February 2, 1989 The shaft excavation was finished at elevation 508, 3.6 feet above the invert, on June 19, 1989. The TBM hole-through was on July 13, 1989.

5-07. Maintenance Shaft Excavation. The maintenance shaft excavation was performed according to the contractor's approved submittal, which generally provided the specified shaft dimensions. The excavation was accomplished primarily by two drilling subcontractors between May 9 and August 11, 1988.

Cato Electric and Drilling began the work by drilling a ring of 27 concrete soldier piers around the shaft circumference. These 36-inch diameter piers were intended to provide initial support through the alluvial overburden into the underlying weathered, but impervious, clay shale. At Ohbayashi's field discretion, however, the piers were extended through the weathered clay shale into the underlying unweathered formation at depths of 36 to 42 feet. The procedure was to auger every other pier, and backfill it with 3000 psi concrete. The intermediate piers were then augered with a minimum of 1-inch overlap on the adjacent piers, and likewise backfilled with 3000 psi concrete. This overlapping established an 8-inch bearing surface from pier to pier, and provided a ground water barrier through the alluvium.

The 21.5-foot wide interior of the soldier pier ring was then excavated by Ohbayashi with a backhoe. To prevent any possible inward movement of the piers, W8 X 35 steel rings were installed at ground surface, at about the 15-foot depth, and at about the 30-foot depth. The backhoe excavation continued below the piers to the 50-foot depth, enlarging the diameter to 22 feet. Below the piers, the excavation was supported with a 6-inch nominal thickness of shotcrete.

Beck Foundation Company drilled the remainder of the shaft with a Northwest 5045 crane-type rotary drilling rig. A 3-foot diameter pilot boring was first drilled to the 122-foot total depth. Then progressively larger bores of 4 feet, 6 feet, and 8 feet were drilled to various depths. After reaching an 8-foot diameter the shaft was enlarged by progressively reaming to diameters of 11 feet, 16 feet, 19 feet, and finally to 22 feet 4 inches. The 6 nominal inches of shotcrete support was generally applied when a 7-foot deep tier had been reamed to the final diameter. The pilot bore served as a catchment for the drill cuttings, and was cleaned out periodically with an auger.

The shaft was excavated 122.0 feet from the ground surface elevation of 642.5 to a bottom elevation of 520.5. This placed the shaft 7.5 feet below the crown elevation of the unexcavated tunnel. The shaft was then backfilled with sand to elevation 530. This allowed the final concrete liner to be placed upward from that elevation to an inside diameter of 18.0 feet.

The intersection of the maintenance shaft with the tunnel was excavated to tunnel springline for approximately 16 feet to each side of the shaft centerline. The excavation was done by roadheader, backhoe, and pneumatic spaders in advance of the TBM tunneling, and extended from Station 181+58 to Station 181+90. It was supported with W8 X 48 steel ribs set on 4-foot centers, shotcrete as needed, and wooden lagging. The lower half of the tunnel was supported by the precast concrete liner as the TBM completed the excavation below springline. Finally, the upper half of the tunnel and the shaft intersection were formed and cast with 4000 psi reinforced concrete.

5-08. Vent Shaft Excavations. The vent shafts were excavated and supported according to the contractor's approved submittal. Two 6-foot diameter drilled vent shafts were specified for San Pedro Creek Tunnel, and were to be lined with a 4-foot inside diameter precast concrete pipe. However, to connect the tongue and groove pipe joints with O-ring gaskets would have been somewhat difficult, as would the inspection in these deep, narrow shafts. Therefore, the Government approved the contractor's proposal to install a 4-foot inside diameter, 3/8-inch thick, steel casing from the ground surface. The general shaft dimensions were not changed.

In May 1988, Beck Foundation Company augered both vent shafts using a Northwest 5045 crane-type rotary drill rig. The first vent shaft was located just north of Durango Street at tunnel Station 158+14.13, and was drilled to the 121.0-foot depth. The shaft was then backfilled with drill cuttings to the 117.7-foot depth, to which depth the permanent steel casing was seated. The second vent shaft was located near the intersection of Camaron and Salinas Streets at tunnel Station 185+73.90, and was drilled to the 117.0-foot depth This shaft was also backfilled with drill cuttings to provide a seat for the permanent steel casing at the 114.0-foot depth.

The general construction procedure for each shaft was to auger an oversized bore through the alluvial overburden and set a temporary surface casing into the impermeable clay shale. The remainder of the shaft was then augered to a minimal 6-foot diameter, and backfilled with drill cuttings to the permanent casing depth, about 5 inches above the projected tunnel bore. The 4.0-foot inside diameter steel casing was installed with the 1.0-foot wide annular space backfilled with 3000 psi concrete. The temporary casing was removed as the concrete backfill approached the ground surface.

No further excavation was required for the intersection of the vent shaft and the tunnel, other than minor spading for a concrete ring beam at the junction. The TBM excavated through the bottom of the shafts removing the backfill cuttings through the mucking system. As the precast segmental liner was erected through the shaft area, the crown key segments were omitted and replaced by W6 X 20 steel sets and wood lagging. At the Durango Street shaft five key segments were omitted between Stations 158+10 and 158+30. However, at the Salinas Street shaft only one key segment at Station 185+74 was omitted. The intersections were later formed and cast with 4000 psi reinforced concrete.

5-09. Hydraulic Instrumentation Shaft Excavations. The two hydraulic instrumentation shafts for San Pedro Creek Tunnel were constructed according to the contractor's approved submittal. The submittal provided for a 12-inch inside diameter, Schedule 40 steel cased shaft as specified.

However, there were a few changes proposed in the procedures. One change was to drill a 24-inch diameter boring rather than the specified 16-inch boring. Also, since the upstream shaft was actually located within San Pedro Creek, a 54-inch diameter surface casing was used as a work caisson through the water, and a 24-inch diameter corrugated metal pipe, C.M.P., was installed as a permanent stick-up above the creek surface.

Both of these shafts were drilled in April 1988 by Beck Foundation Company using a Northwest 5045 crane-type rotary drill rig. One shaft was located near the outlet shaft at tunnel Station 143+00. It was drilled to the 119.2-foot depth, and was backfilled with 2 feet of drill cuttings to provide the permanent casing seating at the 117.2-foot depth. The other shaft was located in the creek channel near the inlet shaft at Station 199+81. Its drilled depth was 107.0 feet with permanent casing set 2 feet higher on backfilled drill cuttings.

The general construction procedure was first to drill an oversized hole through the overburden and set temporary casing into the impervious clay shale. The remainder of the shaft was then augured at a 24-inch diameter to the total depth. The lower 2 feet of the hole was backfilled with drill cuttings to provide a casing seating about 5 inches above the projected tunnel bore. This was followed by the installation of the 12-inch diameter, Schedule 40 steel, permanent casing. The annular space was backfilled with sand-cement grout, and the temporary casing was removed as the grout approached the ground surface.

The upstream shaft, being in the creek channel, had a couple of additional features. To prevent the stream flow from entering the shaft, a temporary 54-inch diameter steel casing was installed to a depth of 3 feet below the channel, and was removed when the construction was completed. Also, a permanent outer casing was installed at the surface to provide a stick-up of about 2 feet above the water level. When the cement backfill had been poured around the 12-inch diameter permanent casing up to the stream channel, a 24-inch diameter, 16 gauge C.M.P. was pressed into the cement to form an outer casing through the water. The annular space between the C.M.P. and the Schedule 40 casing was also backfilled with the cement

No further excavation was required for the intersection of the shaft and tunnel. The TBM cut through the lower portion of the shaft and removed the backfill cuttings. A 12-inch diameter hole was cut through the precast tunnel liner to access the bottom of the shaft. A sona-tube form was secured between the tunnel liner and the shaft casing. The annular space behind the tunnel liner was then filled with pea gravel, and finally grouted around the sona-tube.

5-10. Tunnel Excavation. As discussed in preceding paragraphs, the tunnel was excavated by a modified Robins TBM and supported with a precast concrete segmental liner. The TBM excavated the 5,843-foot long tunnel to a diameter of 26 feet 11 inches. The precast liner, consisting of 6 segments per ring, was installed within the TBM tail shield by a circular erector arm located about 38 feet behind the heading The liner segments were 4 feet wide and 1 foot thick giving the tunnel an inside diameter of 24 feet 4 inches with an outside annular space of 3.5 inches The liner was primarily supported with pea gravel blown into the annular space and later grouted with 1:1 cement grout (water-cement ratio by volume) about 500 feet or more behind the heading The specified lines and grades of the excavation were controlled by laser beam instrumentation.

Although the tunnel excavation encountered no major problems, the rate of advance averaged only half of the anticipated 60 feet per day. The work schedule consisted of two 10-hour shifts per day which usually included Saturdays. The largest advance in a day was 106 feet on July 9, 1989, but the average was 30 feet. The average rate was lowered considerably by the 107 workdays required to complete the first 700 feet of tunnel. This slow start was attributed to an initial learning curve for the workers, mechanical problems, the Christmas holiday season, and the typical difficulties of starting tunnel construction on a curve section; the first 600 feet of the tunnel were in a curve. After the first 700 feet, the tunneling progress improved with only occasional delays. These minor delays were generally only a few days in duration, and often due to the contractor's difficulty in keeping the pea gravel and grouting operations in pace with the excavation rate.

This lag in the pea gravel and grout backpacking became a major concern to the Government, since it was the contractor's proposed primary means of providing positive structural support for the precast segmental liner It was essential for safety and the operational longevity of the tunnel to provide a stable circular liner and to secure that liner with a solid, uniformly grouted contact with the surrounding rock. The circularity of the liner had to be preserved to prevent differential pressures developing around the tunnel. The annular void behind the liner had to be completely filled to prevent deterioration of the surrounding clay shale and to create a uniformly structural contact. Therefore, a timely and thorough placement of pea gravel and grout were crucial not only as initial liner support, but also as final liner stabilization. When the contractor became lax in properly executing these essential operations, the Government was obliged to stop the tunnel excavation until the liner erection procedure was brought into full compliance with the approved plan. When pea gravel support was lacking behind the liner and/or when grouting lagged too far behind the excavation, the Government directed the contractor to cease tunnel excavation until these operations were caught up. These cease work orders were issued five times on the following dates: March 2, March 23, April 7, June 16 and June 19, 1989.

The tunnel excavation began on November 7, 1988 with a scheduled completion date of March 7, 1989. The TBM holed-through into the inlet shaft at 06:05 p.m. on July 13, 1989. This was Thursday evening; the contractor worked a partial crew the next day, but no one worked on Saturday or Sunday. Therefore, completion was four days later on Monday, July 17 when the TBM had passed to the back of the shaft (excavating the lower 3.6 feet) and all of the tunnel liner had been set.

See Appendix B for tunneling progress charts.

PART VI

CHARACTER OF FOUNDATION OR TUNNELING MEDIUM

6-01. General. As anticipated, the Taylor Formation proved to be a relatively stable tunneling medium. It was the only rock formation encountered, and it's generally massive character persisted throughout the excavations. The rock was soft enough to readily excavate without blasting, and yet firm enough to stand well in vertical cuts. Minor crown fallout or block settlement occurred in the softer strata due to excessive exposure before the rock was fully supported; however, these were indeed minor and of little construction consequence. Some inevitable stress relief fracturing occurred, but joints and fractures were generally sparse. In short, the San Pedro Creek Tunnel and Shafts were constructed in impermeable, massive, structurally competent, but variably expansive clay based rock.

The following paragraphs summarize the ground conditions encountered in the tunnel and in each shaft.

6-02. Tunnel Foundation or Medium. The Taylor Formation provided a massive, competent, stable rock medium throughout the tunnel, however, the material varied somewhat along the alignment. As the tunnel was excavated upstream from outlet to inlet it passed through successively older strata within the formation. This was due to the .002 upstream grade, a 2 degree southeastward dip of the bedding, and 32 feet of down-to-the-south faulting at about Station 171+50. These strata were identified from youngest to oldest as M-1 through M-5, and as previously discussed in Part III, the stratigraphically lower and older beds increase in carbonate content. The result is that the M-1 and M-2 materials are more clayey and not as strong as the better indurated limy materials of the M-3 through M-5 strata. Therefore, the first 2,892 feet of tunnel, which was on the downthrown side of the fault, encountered lithologically weaker M-1 and M-2 materials, whereas the 2,951 feet of tunnel upstream of the fault encountered the stronger M-3 and M-4 materials.

These stratigraphic changes in the clay to calcium carbonate ratio presented a pronounced material contrast across the fault at Station 171+50, which roughly divides the tunnel length in half. The M-1 and M-2 strata in the downstream half is dark gray, unctuous, massive, soft to moderately sott, variably calcareous, geologically consolidated or slightly indurated clay based rock which with fissility forms a clay shale or otherwise, where nonfissile, could be classified a claystone. This is the weaker material of the formation having an unconfined compressive strength as low as 5 tsf, but normally around 25 tsf. In the upstream half, the M-3 and M-4 strata (also M-5, though it is below the tunnel elevation) is gray to light gray, earthy, massive, moderately soft to moderately hard with occasional hard lenses, very calcareous or limy, well indurated clay based rock which can be called a clay shale where fissile or claystone where nonfissile. Actually, much of this lower portion of the formation has the high carbonate/clay mixture of an indurated marl and could be classified as a marlstone, or an argillaceous limestone where the calcium

carbonate predominates. This is the strongest material of the formation having unconfined compressive strengths normally around 70 tsf.

These material descriptions give the predominant characteristics of the strata. However, it should be noted that stringers of limy shale occur occasionally in the upper strata, and occasional clayey shale layers occur in the lower strata.

The downstream M-1 and M-2 clayey materials tended to deteriorate when subjected to extensive unsupported exposure by slow tunneling progress. Some crown fallout and block settlement occurred, but nothing large or of long term detriment. As tunneling began the TBM moved only 36 feet in the first 8 days with the result that fallout developed to 2 feet above the crown for the first 7 feet along the alignment. Further, the generally slow progress in much of the downstream tunnel caused the tunnel bore to be unsupported around the TBM for as much as 5 or 6 days before a cut-section would progress back to the tail shield where the liner could be installed. The material was thus exposed for an extended time to desiccation, air-slaking, and the opening of stress relief fractures. Nevertheless, no major fallouts developed. Some block settlement was noted in places on the TBM shield and over the crown of the liner, but no blocks ever fell around the shield into the invert. Although there was some concern that block settlement at times was warping or deflecting the crown of the tail shield downward, the tightness of the shield against the material could also be attributed to the undulatory maneuvering of the TBM. In addition, a thin 1/4 to 1/2-inch layer of compressed ravelings was sometimes noted at the tail shield cut-out section, which indicated that muck cuttings and/or slaking material was falling around the TBM

The massive character of the formation was always obvious in the cut-out section of the tail shield, and it is doubtful that any exceptionally large blocks ever settled out of the crown. The fact that only 15 of 56 borescope holes in this section of tunnel had fractures is indicative of the persistent massiveness of the formation. Also, all but 2 of the borings with fractures were above springline which suggests that these few fractures were stress relief development in the crown through several days of unsupported exposure. (Borescope observations were conducted in 8-foot deep borings, 7 holes per station spaced 45 degrees apart around the tunnel bore, at Stations 143+63, 143+71, 143+79, 143+87, 143+95, 158+39, 158+47, and 158+55)

A concern derived from fallout behind the liner was in the pea gravel and grout backpacking operation Chunks and ravelings of deteriorated material fallen around the outside of the liner obstructed the thorough placement of pea gravel throughout the annular space Voids left by the fallout and open joints required a determined effort to insure that all empty space surrounding the liner was filled with pea gravel and/or grout However, though some secondary grouting was required, final test borings through the liner to 5 feet within the rock indicated that there was good grout penetration and complete rock consolidation about the liner This was imperative to maintain the longterm integrity of the surrounding ground, and to prevent differential pressures from developing against the tunnel liner

Both the material strength and the tunneling rate improved in the upstream half of the tunnel. The better indurated limy M-3 and M-4 materials were more resistant to deterioration, and the unsupported exposure time decreased from several days to a day or less as the tunneling operation improved. As a result, there was no fallout or block settlement upstream from the fault at Station 171+50.

6-03. Outlet Shaft Foundation. The outlet shaft was excavated through 27 feet of alluvial overburden, 13 feet of weathered Taylor Formation, and 111 feet of unweathered Taylor Formation. The alluvial overburden included, from the ground surface downward, 4 feet of clay fill, 3 feet of clay, 2 feet of silt, 10 feet of gravelly clay, 2.5 feet of sand, and 5.5 feet of gravel. Ground water at 200 gpm occurred between the top of the sand layer at the 19-foot depth and the weathered clay shale at the 27-foot depth. The weathered clay shale of the Taylor was tan with gray mottling, soft, generally massive with occasional fractures. The unweathered Taylor was gray to dark gray clay shale, predominantly soft to moderately hard in places, massive, variably calcareous, and occasionally jointed or fractured.

Though the Taylor at the outlet shaft was the younger and softer portion of the formation, it was a sound, firm foundation rock. The top of the M-1 stratigraphic marker bed was at about elevation 524; this was at the 115-foot depth or about 10 feet below the crown of the shaft-to-tunnel transition. Nevertheless, all of the rock formation throughout the shaft was the uppermost Taylor, and essentially the same characteristic material. This was the more clayey and less limy material of the downstream tunnel alignment, which excavated easily while standing very well in vertical cuts. There were a couple of fallout slabs from the crown of the horizontal transition section; the dimensions of one was 6 feet by 4 feet by 2 feet and the other was 6 feet by 3 feet by 1/2 foot. These fallouts were derived from stress relief partings along bedding planes due to a delay in shotcrete applications. Normally, excavation surfaces were smooth showing little disturbance to the in situ character of the material.

The formation was typically massive with only occasional fractures or joints. A few irregular discontinuous fractures were noted in the weathered clay shale in the northern half of the shaft. One nearly horizontal, relatively tight joint striking east and dipping 1 degree north was mapped at elevation 578, the 61-foot depth. Several nearly horizontal bedding plane partings were noted around the 100-foot depth, between elevations 539 and 535. Another essentially horizontal joint opened at the top of a 1-inch thick, white bentonite seam at the 107.5-foot depth, elevation 531.5. Several fractures developed in the lower 12 feet of the transition with apparent dips to the northeast and southwest at 1 to 10 degrees.

6-04. Inlet Shaft Foundation. Being on the upthrown side of the tunnel fault, the inlet shaft extended through four of the stratigraphic units identified within the Taylor Formation. The excavation began in the M-1 material at elevation 623, and the M-2 bed was 16 feet lower at elevation 607 The M-3 and M-4 beds began at elevations 583 and 514 ,respectively, the 40-and 109-foot depths. It is noteworthy that a moderately hard to hard limy shale layer was located at the top of each of these stratigraphic units, these are

the marker beds which are distinguishable on electric logs. Throughout the shaft the material was true to the character of each stratigraphic unit, progressing downward from soft clayey rock in the upper strata to harder, limy, well indurated rock at depth.

The entire inlet shaft is constructed within unweathered Taylor Formation, since the overlying weathered and alluvial materials were removed previously during the approach channel work. The upper 62 feet of the shaft is in mostly soft strata which excavated smoothly with little disturbance to the in situ formation. However, the harder rock in the lower 57 feet of the shaft required percussion excavation by hydraulic ram. Although the excavation was controlled somewhat by indistinct horizontal bedding, the material tended to break in conchoidal, angular patterns giving a slightly rough texture to the excavated surface. Tight, thin, discontinuous, and apparently shallow fractures developed along the nearly horizontal bedding planes between elevations 532 and 525, the 91-to 98-foot depths. The formation stood well throughout the shaft excavation, and the well indurated rock in the lower shaft stood extremely well in both vertical and horizontal cuts. The increased carbonate to clay ratio of these lower strata made the rock harder and more brittle, but also less susceptible to desiccation, air slaking and sloughing.

The formation was persistently massive. There were relatively few fractures, and no major joints that extended completely through the shaft. A few irregular discontinuous fractures were located in the upper 3 feet of the southern half of the shaft. Some nearly horizontal discontinuous fracturing was noted at elevation 608, the 15-foot depth. A nearly horizontal, calcite healed joint was noted at elevation 584, the 39-foot depth, but did not extend through the N-NE quadrant of the shaft. In the shaft's S-SW quadrant, between elevations 539 and 536, there were two discontinuous joints with apparent dips of 2 degrees and 3 degrees SE. The few other fractures were thin, tight, short, and probably shallow breakage planes caused by the percussion excavation.

6-05. Maintenance Shaft Foundation. The maintenance shaft being located at tunnel Station 181+77 is on the upthrown side of the fault at Station 171+50. Therefore, like the inlet shaft, it extends from the softer, clayey M-1 strata near the surface into the harder, more limy, and better indurated materials at depth. The maintenance shaft, however, does not extend beyond the M-3 strata, since it is structurally down-dip from the inlet The top of the M-2 strata is at elevation 582.5, the 60-foot depth, and the top of the M-3 is at elevation 562.5, the 80-foot depth. The top of the M-4 strata is correlated at elevation 501, which would be 19.5 feet below the shaft

The maintenance shaft is constructed through 16.0 feet of overburden and 106 feet of Taylor Formation. From surface elevation 642 5, it extends progressively downward through 7.3 feet of clay fill, 8.7 feet of clay, 17 8 feet of weathered clay shale, 8 7 feet of partially weathered clay shale, and 79.5 feet of unweathered clay shale Due to the impermeable character of both the overburden and the primary formation, there is no observable ground water other than sparse wetness in the overburden. The upper 44 feet of weathered and unweathered clay shale is soft, clayey M-1 material Below the 60-foot

depth, the M-2 strata becomes interbedded with moderately hard limy layers of several inches thickness. A 6-foot thick limy bed occurs at the 70-foot depth. Below the M-3 contact at the 80-foot depth the material is generally moderately soft to moderately hard, more limy, and well indurated. A moderately hard, very limy zone extends between the 90 and 95-foot depths.

The Taylor Formation at the maintenance shaft was massive below the 42-foot depth. The weathered and partially weathered material of the upper shaft was fractured with an average spacing of about 5 feet, although it varied from less than 1 foot to 12 feet. Except for nearly horizontal joints at the 40 and 42-foot depths, the fractures were mostly high angle. Those which occurred in the largely unweathered material below the 33.8-foot depth were channels for chemical weathering; weathering had oxidized the shale from gray to reddish tan in 1 to 2-inch wide bands along the fractures. Since the shaft was excavated by drilling and reaming, the scraping of the reaming blades along the shaft walls may have obscured occasional tight fractures or joints in the lower shaft. However, the formation appeared unfractured below the 42-foot depth, and no sloughing occurred.

6-06. Vent Shaft Foundations. The two vent shafts for San Pedro Creek Tunnel were drilled on each side of the fault at Station 171+50. The vent shaft near Durango Street is located at Station 158+14 on the downthrown side of the fault, and in the soft, clayey Upper Taylor Formation. The top of the M-1 strata is at elevation 529.3, the 110-foot depth or 11 feet above the bottom of the shaft. The vent shaft near Salinas Street is located at Station 185+74 on the upthrown side of the fault, and extends from the softer, clayey M-1 strata into the harder limy M-3 materials. The top of the M-2 strata is at elevation 601, the 42-foot depth, and the top of the M-3 is at elevation 578, the 65-foot depth. The top of the M-4 strata is correlated at elevation 510, the 133-foot depth or 16 feet below the bottom of the shaft.

The Durango Street vent shaft at Station 158+14 extends through 23.0 feet of overburden, 16.8 feet of weathered Taylor Formation, and 81.2 feet of unweathered Taylor Formation. Progressively downward, the overburden includes 1.5 feet of sand fill, 10.5 feet of gravelly clay, and 11.0 feet of clayey gravel. Free water was encountered between the 16.0 and 23.0-foot depths when the shaft was drilled in May 1988. The weathered Taylor consists of soft, fractured clay shale. The unweathered Taylor is soft, massive, variably calcareous clay shale. The formation stood well with no sloughing during the shaft sinking.

The Salinas Street vent shaft at Station 185+74 extends through 13.58 feet of overburden, 17.42 feet of weathered Taylor Formation, and 86.0 feet of unweathered Taylor Formation. The overburden consists of 2 5 feet of gravelly clay fill overlying 11.08 feet of clay. During the shaft sinking in May 1988, only a small amount of ground water flowed along a joint at the 13.0-foot depth and along the formation contact at the 13 58-foot depth. The weathered Taylor is soft, fractured clay shale at this shaft also. The unweathered Taylor begins in the soft, clayey M-1 strata, but is increasingly moderately soft and more calcareous in the M-2 below the 42-foot depth. Below the 65-foot depth, the M-3 strata is moderately soft to moderately hard with

highly calcareous or limy layers. The formation was massive and stood well; no sloughing occurred during construction.

6-07. Hydraulic Instrumentation Shaft Foundations. Like the vent shafts, the two hydraulic instrumentation shafts were drilled on each side of the fault at Station 171+50. One of the shafts is located near the outlet at Station 143+00. It is on the downthrown side of the fault, and is in the soft, clayey Upper Taylor Formation. The top of the M-1 strata is at elevation 522, the 116-foot depth, or 3.2 feet above the bottom of the shaft. The other shaft is at Station 199+81 near the inlet, and is on the upthrown side of the fault. It begins in the soft, clayey M-1 strata, and extends well into the harder, limy M-3 strata. The top of the M-2 strata is at elevation 605, the 30.8-foot depth, and the top of the M-3 is at elevation 580.8, the 55.0-foot depth. The M-4 is correlated at elevation 512, the 123.8-foot depth, or 16.8 feet below the bottom of this shaft.

The hydraulic instrumentation shaft near the outlet extends through 27.0 feet of overburden, 12.6 feet of weathered Taylor Formation, and 79.6 feet of unweathered Taylor Formation. From the ground surface downward, the overburden consists of 2 feet of clay fill, 10 feet of clay, 8 feet of gravelly clay, and 7 feet of clayey gravel. The lower 7 feet of clayey gravel contained free water during construction in April 1988. The weathered Taylor Formation is soft, fractured clay shale. The unweathered Taylor is soft, massive, variably calcareous clay shale, but has occasional thin, moderately soft to moderately hard, highly calcareous layers. The formation stood well without sloughing during construction.

The hydraulic instrumentation shaft near the inlet extends through 0.8 feet of concrete channel liner in San Pedro Creek, 11 feet of weathered Taylor Formation, and 95.2 feet of unweathered Taylor Formation. There is no alluvial overburden at this site since channel improvements to the creek have placed concrete liner directly on weathered clay shale of the Taylor Formation. The weathered clay shale is soft and somewhat blocky, but with little indication of fracturing. During the drilling in April 1988, a trace of free water was observed at the 5-foot depth; this could have been seepage around the 3-foot deep surface caisson or ground water flow along a formation fracture. The unweathered Taylor Formation is soft, clayey M-1 and M-2 strata in the upper 55.0 feet of the shaft. Moderately soft to moderately hard, limy zones increase with depth through the underlying M-3 strata The formation was massive and stable with no sloughing during construction.

PART VII

FOUNDATION TREATMENT

7-01. General. There was no major foundation treatment required for the tunnel or shafts. However, two of the support procedures may also be considered methods of foundation treatment. These two operations were the rock anchor installations in the shafts and the grouting of the tunnel liner. Although both the rock anchors and the grouting were required as part of the excavation support, they may also be considered foundation treatment in that they enhanced the in situ stability of the rock formation. These operations have been described as support procedures in Part V, but will be further discussed in this section.

7-02. Rock Anchors. There were three general types of rock anchors used on the San Pedro Creek project. Type I and Type II rock anchors were used in the outlet shaft. Type I and Type III rock anchors were used in the inlet shaft. The type differences consisted of variations in length and corresponding bonding capacities. The rock anchors were normally stressed to design loads and then locked off at 80% of that load, which varied with the length of the rock anchor. Type I rock anchors were 18 feet long, had a design load of 90 kips, and a lock-off load of 72 kips. Type II rock anchors were 21 feet long, had a design load of 110 kips, and a lock-off load of 88 kips. Type III rock anchors were 15 feet long, had a design load of 100 kips, and a lock-off load of 80 kips. The Type III anchors were used exclusively in the better indurated rock at the inlet shaft, and thus had a higher bonding capacity for the shorter length of anchor.

All three types of rock anchors were similar in materials and construction. They were all 1.25-inch diameter, No. 10 Dywidag threadbars, and were cement grouted into 5-inch diameter holes. The anchor grout was a non-corrosive expansive admixture with a minimum 28 day compressive strength of 3000 psi The recommended pumping pressure for the grout was 30 psi. PVC spacers were used at equal distances along the boring to keep the anchor in the center of the hole. A 2-inch thick, 5-inch diameter styrofoam donut was placed around the anchors at the 1.0 to 1.5-foot depth to act as a grout barrier; the styrofoam was also supposed to provide a compressible cushion which would allow the anchor bar to move if the bonding capacity was exceeded during the stress loading. The outer foot or so of hole beyond the styrofoam donut was backfilled with dry-pack cement around a PVC bond breaker covering the anchor bar An 8 to 10 inch square, 1.5-inch thick Dywidag bearing plate was installed against the shotcreted shaft surface at the outer end of the anchor bar.

The design of these rock anchors provided a support effect similar in principal to "soil nails" rather than typical rock bolts Soil nails are normally relatively short steel bars of a fully bonded length installed as reinforcing inclusions to the in situ ground. Usually closely spaced, they produce a zone of reinforced ground which performs in a manner similar to a retaining wall. Soil nails are not stressed although it is common to apply a

small seating load. Unlike soil nails, rock bolts are stressed after installation with the load transferred along a distal, fixed anchorage length; this distal anchorage binds the unbonded outer rock to the more stable ground mass at depth. The rock anchors in the outlet and inlet shafts were stressed like rock bolts, and yet, like soil nails, they were bonded for nearly their entire length. Only the outer 1.0 to 1.5 feet of bar length was unbonded. Considering the thickness of shotcrete on the shaft wall, this left only the outer few inches to 1.0 foot of rock unbonded, and the stressing load was distributed along the rest of the bar. Therefore, the rock anchors acted as stress loaded soil nails rather than bolts anchored at depth.

Although this type of rock anchor appeared to work satisfactorily in the massive rock of the San Pedro Creek shafts, there is some doubt that the anchors could actually sustain their submitted design load. Load tests on instrumentation rock bolts in the soft clayey rock at San Pedro Creek Outlet Shaft had difficulty in achieving a required 20 kips test load. It was therefore questionable that 90 to 110 kips were achieved on support rock anchors at this same shaft.

The contractor's method of stressing the support rock anchors was somewhat dubious. The method of stressing placed the jacking frame against the bearing plate which covered the grouted anchor hole and rested on the shotcreted shaft wall. When a load was applied to the jacking frame, the bearing plate restrained the grout column from moving. Thus, the bond between the grout and rock could not break if its normal load capacity was exceeded. If failure occurred it would have been at the relatively strong bond between the anchor bar and the grout column. It was intended that the 2-inch thick styrofoam donut would collapse enough to allow failure of the grout-to-rock bond However, this was rather speculative since the strength of the styrofoam under complete confinement was unknown.

In any case, these rock anchor "nails" apparently provided an effective reinforcement in the massive rock at the San Pedro Creek shafts, and no support problems developed. However, in jointed, more thinly stratified, blocky ground as at the San Antonio River Outlet Shaft these anchor nails would be less effective than the longer typical rock bolts having a distal anchorage at depth. This is more relative to the forthcoming foundation report on the San Antonio River Tunnel. Nevertheless, it is significant to mention that random failure and creep tests performed on Type I rock anchors at that outlet revealed load capacities of only 16 to 38 kips in similar soft, clayey rock. As a result, the anchor loading procedure was eventually changed to use a jacking frame large enough to straddle the bearing plate. This left the grout column free to move if the anchor failed.

Although three general types of rock anchors were used for the most part in the San Pedro Creek shafts, there was actually a fourth type This fourth type of anchor was used in only two places at the inlet shaft, and was not a major design requirement There were 24 of these resin grouted, 8-foot long, 3/4-inch diameter anchors installed at elevations 617 and 612 in the upper 21 feet of the shaft. These small anchors were only a precautionary measure added to the support design, which required only 3 inches of shotcrete for the upper shaft

7-03. <u>Tunnel Liner Grouting.</u> Grouting of the annular space between the tunnel liner and the surrounding rock was primarily to establish a solid contact between the liner and the rock, but it also consolidated the surrounding rock by filling open fractures, joints, and occasional elongated voids left by minor block settlements in the crown. Grouting behind tunnel liners is usually called backpack grouting, and is largely for support. The grouting of fissures and voids in the loosened rock surrounding tunnels is referred to as consolidation grouting, and is predominantly a stabilization treatment. Consolidation grouting often requires the drilling of grout holes to the depth of formation disturbance to provide a full distribution of the grout. However, the zone of disturbance in the massive material surrounding the San Pedro Creek Tunnel was only several feet thick. Therefore, backpack grouting and consolidation grouting were effectively accomplished in the same operation as the grout pumped behind the liner also penetrated well into the relatively shallow fractures.

The grouting procedure proved to be reasonably thorough although it was done in a patchwork fashion. The procedure was to grout in horizontal strips at various locations with a general upward progression from the invert holes. Two 2-inch diameter grout holes were constructed in each liner segment which allowed the upper holes to provide venting and observation ports. Injection holes were moved vertically and horizontally beyond holes which were plugged due to previous grout flows. Adjoining grout sections would overlap previous grouting, or upstream grouting sections would merge with advancing downstream sections. Grouting at the crown required sustained pumping at gravity flow until pressure could be obtained or a secondary grouting which could maintain pressure. This method eventually produced a forward slope of grout from a downstream injection point in the crown to an upstream edge in the invert, covering approximately 200 feet of alignment. The grout was a 1:1 cement to water ratio by volume, and was pumped at a maximum pressure of 28 psi.

Quantitative data on the pea gravel and grout placement shows that the primary backfilling extended well around the liner into the crown annular space (See Appendix C). The volume of the 3.5-inch wide annular space was calculated to be 98 cubic feet per 4-foot liner ring; however, it should be noted that part of this void was no doubt filled with rock cuttings or rubble in places. A pea gravel density of 95 pounds per cubic foot was used to compute the amount of pea gravel backfilled behind the rings, which averaged 46 cubic feet per ring. The average placement of grout per ring was estimated at 55 cubic feet. The pea gravel volume included approximately 40% voids which would consume part of the grout placement. Therefore, of the 98 cubic feet of annulus behind each ring, 46 cubic feet was filled with pea gravel and 37 cubic feet was filled with grout. This gave an average of 83 cubic feet of backfilled pea gravel and grout which was 85% of the annular space. Since much of the invert liner was placed directly on the excavated surface, most of the void was in the crown rather than arranged concentrically into a 3.5-inch wide annular space. Thus, the 85% backfill would extend well into the crown area after the primary pass of grouting.

The 85% backfill estimate may be considered a best case scenario since it is based on bulk placement quantities and ignores material wastage On the other hand, this wastage would be partially offset or possibly exceeded in places by

the volume of rock settlement and ravelings. Also the amount of grout required to fill the pea gravel voids is somewhat speculative and subject to variables such as the presence of extraneous moisture and granular fines. In any case, the remaining annular space was filled by secondary pressure grouting conducted in crown borings spaced on 50-foot centers along the tunnel alignment.

A core sampling investigation by the Government determined that the grouting operation had effectively accomplished both the backpacking of the tunnel annular space and the consolidation of the surrounding rock. Three 100-foot long test sections were established at Stations 148+94 to 149+94, 169+98 to 170+98, and 189+82 to 190+82. Core sampling was conducted through the liner grout holes at every fifth ring in each test section. Four core samples were taken at each test ring, one in each quadrant, with a rotational sequence from ring to ring so that all 12 grout hole positions were sampled in each 100-foot test section. Core sampling was extended to the depth of solid, undisturbed rock in each hole, which was generally within 5 feet of the tunnel bore. Also, to determine the effectiveness of consolidation grouting in a reach of known rock settlement, core samples were taken every 50 feet in the crown between Stations 142+87 and 148+55. Eight other borings sampled beneath the invert liner between Stations 166+22 and 179+82. The findings of all 93 core borings indicated that grout had penetrated well into all fractures surrounding the tunnel bore and, except where liner segments rested directly on the excavated surface, the annular space had been completely filled.

See Appendix C for grouting data.

PART VIII

CONSTRUCTION MATERIALS

The earth materials used in the Phase II tunnel construction consisted of pea gravel and concrete aggregate. These materials were obtained from local San Antonio suppliers. The pea gravel used as tunnel liner backfill was supplied by Capitol Aggregates, Inc. at 11551 Nacogdoches. Cast-in-place and backfill concrete was obtained from Pioneer Concrete of Texas, Inc. at 15080 Tradesmen, and contained aggregate supplied by Redland Worth Corporation located at 17910 IH-10 West. The concrete for the precast liner segments, manufactured by Sehulster Corporation at 7386 Grissom Road, was supplied by Meader Construction Company, Inc., whose plant was nearby at 7510 Grissom Road. Aggregate for the Meader concrete was provided at first by Redland Worth Corporation, but later by Vulcan Materials Company. The Vulcan Materials Office was at 800 Isom Road, however the aggregate came from a limestone quarry on Huebner Road relatively close to the precast plant. Concrete aggregate analyses were included in the mix design submittals which were reviewed and approved by the Government.

PART IX

GEOTECHNICAL INSTRUMENTATION

9-01. General. The contract specifications provided for a geotechnical instrumentation program to monitor ground behavior at the outlet shaft and at two designated stations in San Pedro Creek Tunnel. The Contractor, Ohbayashi Corporation, retained the services of Woodward-Clyde Consultants to implement the program, and their Final Instrumentation Report is included as Appendix G of this report. The instrumentation was designed to monitor any ground movements and/or stress developments around the excavations with the intent to provide data for safety observations, design verification, and future design applications. Immediate notification of the Government was required during construction when ground movements exceeded 0.25 inches, or when stresses exceeded 5 kips (34.7 psi) in the outlet shaft, or when stresses greater than 5 tsf (69.4 psi) were indicated in the tunnel. These parameters were not exceeded in the outlet shaft. However, they were exceeded to some extent in the tunnel, but this was considered the localized effects of the tunneling operations. A detailed discussion and interpretation of the instrumentation data can be found in Appendix G. The following paragraphs will describe each instrument installation.

9-02. Outlet Shaft Instrumentation. The outlet shaft instrumentation consisted of 3-position extensometers, rockbolt load cells, and total pressure load cells designated for installation at three elevations -- 604 (35-foot depth), 575 (64-foot depth), and 550 (89-foot depth). However, since bonding rock anchors would be difficult in the clay-like weathered shale at elevation 604, the rockbolt load cells planned for that elevation were installed in unweathered clay shale at elevation 596. Also, to accommodate concrete pours for the permanent shaft liner, the total pressure load cells planned for installation in pairs at elevations 604, 575, and 550 were actually all installed at elevation 564.

Four, 26-foot long, multiple position borehole extensometers (MPBX) were installed horizontally and 90 degrees apart at each of the three designated elevations -- 604, 575, and 550. These were 3-position MPBXs having three measurement rods anchored successively at depths of 3 feet, 11 feet, and 26 feet. The rods were cement grouted into a 27-foot deep, 3-inch diameter borehole. The outer ends of the rods were encased in an electrical sensor head installed in a 1-foot diameter by 2-foot long blockout in the shaft wall. These instruments were designed to measure any horizontal movements in the surrounding ground.

Four, 1-inch diameter, 39.5-foot long rockbolts with load cells (RBLC) were installed horizontally and 90 degrees apart at each of three elevations -- 596, 575, 550. These installations were offset 45 degrees from the MPBX locations. The back 19 feet of the rockbolt was anchored with a two-component resin grout in a 1 5/8-inch diameter hole. The outer 20 feet of the bolt was unbonded in a 3-inch diameter section of the boring, this part of the bolt was wrapped with two layers of bituminous tape and covered for 18 feet with 2-inch

diameter PVC pipe. The outer 6 inches of the bolt extended through a 1-inch thick steel bearing plate into a 1-foot diameter blockout cut into the outer foot of the shaft wall. This outer end of the bolt was mounted with a load cell which was wired for electronic readings and secured with an outer seating nut. The purpose of the RBLCs was to detect rock loads or stresses developing in the shaft walls.

In addition to the MPBXs and RBLCs installed in the surrounding rock , total pressure load cells were installed at the outer edge of the permanent concrete liner. Whereas the other instruments detected movements and loads within the ground, the total pressure load cells were designed to determine stress developments on and within the permanent liner. There were 6 total pressure load cells installed at elevation 564 (75-foot depth) on 60 degree spacings.

9-03. Tunnel Instrumentation. The tunnel instrumentation was designated for installation at Station 143+75 and Station 158+47. The instrumentation specified for each station consisted of a 6-position MPBX, one RBLC, three total pressure load cells, three reinforced concrete strain meters, and eight tape extensometer eye bolts In addition, 18 survey reference/displacement markers were installed on the ground surface between Stations 143+00 and 145+00. Also included with the instrumentation program were 56, 8 foot deep borescope observation holes drilled adjacent to the instrument stations.

A 6-position MPBX was installed in a surface boring above the tunnel at each of the two instrument stations. These MPBXs had six measurement rods cement grouted into 3-inch diameter borings which extended to within three feet of the tunnel crown. The rods were anchored at depths of 60, 80, 89, 99, 107, and 111 feet in a 113-foot deep boring at Station 143+75, and at depths of 64, 84, 94, 104, 111, and 116 feet in a 117-foot deep boring at Station 158+47. The upper ends of the rods were encased in an electrical sensor head installed in a 10-inch diameter by 3.0-foot deep manhole. The purpose of these MPBXs were to measure any vertical movements over the tunnel excavation.

A 1-inch diameter, 39.5-foot long rockbolt with load cell was specified for both tunnel instrumentation stations. These RBLCs were constructed in the same manner as those described for the outlet shaft except for a few changes at the Station 158+47 installation. This RBLC was 45 feet long, and had a 5-inch diameter boring with 25 feet of cement grout anchorage. Both RBLCs were installed through the tunnel liner at about 15 degrees west of the crown center line. Like those in the outlet shaft, these instruments were intended to detect rock loads or stresses developing in the tunnel wall.

Three total pressure load cells and three reinforced concrete strain meters were installed at each instrumentation station. These instruments were installed on a 120 degree spacing around the tunnel liner with a 2-foot offset from the center line. At each location a total pressure load cell was installed in a blockout at the back of the liner with a reinforced concrete strain meter embedded within the liner concrete at the same position. The purpose of these instruments was to detect load distributions and stress developments on and within the liner.

Tape extensometer eye bolts were installed at both instrumentation stations for liner convergence measurements between opposing reference points. There were 8 reference points at each station spaced from the center line at 45 degree intervals. At Station 143+75 an eye bolt was installed at each of the 8 reference points; however, only 6 eye bolts were installed at Station 158+47, since the fan line and muck hauling tracks blocked the crown and invert points respectively.

Although no measurable surface movements were anticipated or actually occurred, survey reference points were established on the ground surface above the tunnel to document that such expectations were valid. There were 18 survey reference points established between tunnel Stations 143+00 and Station 145+00. The top of the hydraulic instrumentation shaft at Station 143+00 and the top of the MPBX at Station 143+75 were established as two of the points. Monument spikes having 3/8-inch square shanks were used for 6 of the points which were located on an asphalt paved driveway. The remaining 10 survey points were in unpaved areas and consisted of a 3/4-inch bar, 4 feet long, driven to flush with the ground surface.

Borescope observations were made in seven 8-foot deep by 3-inch diameter borings cored at each of eight stations along the tunnel alignment. The first set of 35 borings were drilled at Stations 143+63, 143+71, 143+79, 143+87, and 143+95. The second set of 21 borings were drilled at Station 158+39, 158+47, and 158+55. The borings were cored by a Watson drilling rig mounted on the liner erector arm at the back of the tail shield. The erector arm rotated the drill to each of the seven circumferential locations which were on 45 degree spacings with the centerline invert position omitted. The borings were drilled through holes cut in the tail shield and in the cut away shield section below springline. The tunnel face was about 37 feet upstream from the borescope holes during the investigations. Both sets of borings were viewed by Woodward-Clyde and Government representatives with a borescope, and phocographs were taken of fractures with a 35 mm camera attached to the borescope. The second set of borings near instrument Station 158+47 was viewed by the Government with a down-hole video camera.

The first set of 35 borings between Station 143+63 and 143+95 were drilled and investigated between December 23, 1988 and January 5, 1989. Fractures were found in 10 of the 35 borings. The fractures ranged in width from 0.02 inches to 1.6 inches and were mostly along the nearly horizontal bedding planes. All fractures but one were above springline.

The second set of 21 borings between Stations 158+43 and 158+59 were drilled and investigated from March 20 through March 22, 1989 Fractures were observed in 5 of the 21 borings. The fractures ranged in thickness from 0 025 to 1.5 inches, and were mostly along the nearly horizontal bedding planes. Fractures were observed in all three crown borings, in one springline boring, and in only one boring below springline.

See Woodward-Clyde's illustrations, data plots, and detailed evaluation of this instrumentation program in Appendix G.

PART X

FOUNDATION PROBLEM AREAS

The Taylor Formation proved to be a competent tunneling medium, and should cause no future problems. The clay shale was soft enough to excavate easily, and yet, stood well throughout most of the excavations. There were some minor crown fallouts or block settlements in the downstream half of the alignment, particularly in the first 700 feet from the outlet where the tunneling rate was slow. However, the surrounding rock and annular pea gravel have been well consolidated by grouting. This gives a solid, uniform radial contact between the ground and the tunnel liner to insure that no differential pressures develop. The tunnel liner has been designed for potentially high radial swell pressures, and no problems are anticipated.

Due to the expansive nature of the clay shale in places, an effort was made to keep the excavated surfaces dry to prevent moisture induced swelling. However, it was inevitable that some of the rock would be exposed to water from grout bleed-off or unforeseen spillage. There were two particular places along the alignment where the formation was notably wetted, Station 166+22 to 179+82 and in the vicinity of Station 178+49.

The section of tunnel rock between Stations 166+22 and 179+82 was not subjected to a large quantity of water, but remained damp or wet through most of the construction period. The night shift crew during excavation reported that the TBM seemed to hit something hard in this area, and it was speculated that the cutterhead may have clipped an artesian water well that barely intersected the tunnel bore. However, no sign of a well was observed in the tail shield cut-away section below springline. It is rather plausible that the wetness observed in this area was bleed-off water from the grouting operation. Seepage never flowed at any appreciable rate, but wetness would ooze from small water accumulations in the liner grout holes. This slow seepage could well have been grout bleed-off water trapped behind the liner in a pea gravel pocket between grouting zones. The area was grouted twice to insure that all formation fractures were sealed; there was no grout take in the second attempt which indicated that the rock and liner annular space were tight. Although this reach of tunnel rock was wetted for an extended time, the ultimate development of swelling pressure will depend on the expansive clay content at this particular location and the amount of swell dissipation into available openings. In any case, the tunnel liner is designed to support the anticipated swell pressures.

Another section where the tunnel rock was subjected to notable wetting was a reach extending approximately 200 feet to each side of Station 178+49. An abandoned artesian water well was severed by the TBM at Station 178+49 The ground was exposed to well leakage until the liner annular space was grouted past the site after the TBM had proceeded 200 feet beyond it This delay was necessary to allow the TBM trailing gear to pass. The partially sealed well leaked only about 2 gallons per minute, but proved quite difficult for the contractor to plug (see Section 3-02, e). When the liner annular space was

grouted, a hole was left in the liner for a well outlet. Therefore, the well continued to leak inside the tunnel liner for about 5 months, and some seepage no doubt migrated along rock fractures behind the liner. The well was eventually plugged and the surrounding ground grouted, but the rock formation in this area had been subjected to considerable wetting. Nevertheless, little or no swelling is expected in this section because it is in the lower more calcareous portion of the formation; this usually means a correspondingly lower clay fraction with less significant amounts of expansive clay minerals. Also, as stated above, the tunnel liner is designed to support anticipated swell pressures.

There were no serious problems with the geologic conditions encountered by the tunnel and shaft excavations. The notable occurrences mentioned above are documented herein only as information which may have some unforeseen significance at a later date. No future foundation problems are anticipated.

PART XI

RECORD OF FOUNDATION INSPECTIONS AND GEOLOGIC DOCUMENTATION

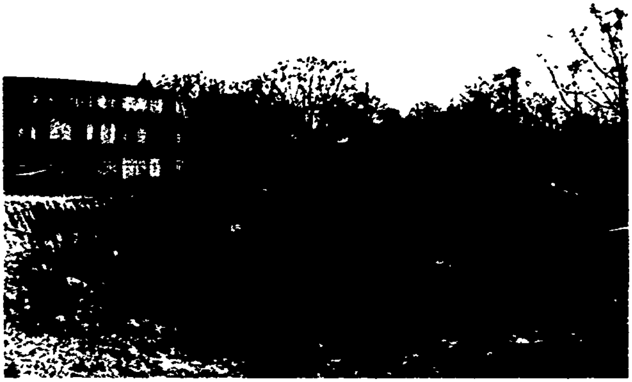
Rock exposures in all shaft excavations were inspected, mapped or logged, and photographed by a geologist. The excavated tunnel bore was observed periodically by the geologist at the tail shield cut-away section below springline. However, no attempt was made to map the tunnel rock due to incomplete exposure, congested working area, and the generally massive, largely featureless character of the rock in this area. The formation was generally soft to moderately hard, massive rock that excavated smoothly and presented few difficulties. The following is a list of mapping and logging dates during the excavation of each shaft:

Feature	Date	Depth Interval Mapped or Logged	Geologist
Hydraulic Inst. Shaft SP-1	25 APR 88	Logged to 119.2	R. Burns
Hydraulic Inst. Shaft SP-5	28 APR 88	Logged to 107.0	R. Burns
Vent Shaft SP-4	2-4 MAY 88	Logged to 117 0	R. Crutchfield
Vent Shaft SP-2	11-13 MAY 88	Logged to 121.0	R. Crutchfield
Maintenance Shaft SP-3	9 MAY-11 AUG 88	Logged to 122.0	Burns-Crutchfield
Outlet Shaft (Mapped)	29 JAN 88	0.0 to 12.0	R. Crutchfield
	9 FEB 88	12.0 to 16.0	R. Crutchfield
	12 FEB 88	16.0 to 20.0	R. Crutchfield
	16 FEB 88	20.0 to 24.0	R. Crutchfield
	19 FEB 88	24.0 to 28.0	Burns-Crutchfield
	23 FEB 88	28.0 to 32.0	Burns-Crutchfield
	29 FEB 88	32 0 to 37.0	Burns-Crutchfield
	2 MAR 88	37 0 to 41.0	Burns-Crutchfield
	16 MAR 88	41.0 to 45.0	Burns-Crutchfield
	25 MAR 88	45.0 to 50.0	Burns-Crutchfield
	29 MAR 88	50 0 to 55.0	Burns-Crutchfield
	1 APR 88	55.0 to 60.0	Burns-Crutchfield
	5 APR 88	60.0 to 63 0	Burns-Crutchfield
	8 APR 88	63.0 to 67 0	Burns-Crutchfield
	13 APR 88	67.0 to 72 5	Burns-Crutchfield
	15 APR 88	72.5 to 77 0	Burns-Crutchfield

Feature	Date	Depth Interval Mapped or Logged	Ceologist
Outlet Shaft (mapped) cont.	20 APR 88	77.0 to 82.0	Burns-Crutchfield
	22 APR 88	82.0 to 85.0	Burns-Crutchfield
	5 MAY 88	85.0 to 91.0	Burns-Crutchfield
	11 MAY 88	91.0 to 95.0	Burns-Crutchfield
	17 MAY 88	95.0 to 99.0	R. Crutchfield
	26 MAY 88	99.0 to 107.0	R. Burns
	6 JUN 88	107.0 to 111.0	Burns-Crutchfield
	13 JUN 88	111.0 to 117.0	Burns-Crutchfield
	1 JUL 88	117.0 tc 122.0	R. Burns
	8 JUL 88	122.0 to 126.0	R. Crutchfield
	23 JUL 88	126.0 to 131.0	R. Crutchfield
	29 JUL 88	131.0 to 135.0	R. Crutchfield
	4 AUG 88	135.0 to 140.0	R. Crutchfield
	8 AUG 88	140.0 to 146.0	R. Crutchfield
Inlet Shaft (mapped)	11 OCT 88	0.0 to 4.0	R Crutchfield
	13 OCT 88	4.0 to 13.0	R. Crutchfield
	15 OCT 88	13.0 to 17.0	R. Crutchfield
	18 OCT 88	17.0 to 21.0	R. Crutchfield
	6 JAN 89	21.0 to 25.0	R Crutchfield
	17 JAN 88	25.0 to 30.0	R. Crutchfield
	20 JAN 88	30.0 to 34.0	R. Crutchfield
	25 JAN 89	34.0 to 40.0	R. Crutchfield
	2 FEB 89	40.0 to 45.0	R. Crutchfield
	9 FEB 89	45.0 to 53.0	R. Crutchfield
	15 FEB 89	53.0 to 62.0	R. Crutchfield
	23 FEB 89	62.0 to 67.0	R. Crutchfield
	7 MAR 89	67.0 to 71.0	R Crutchfield
	23 MAR 89	71.0 to 79.0	R. Crutchfield
	31 MAR 89	79.0 to 87.0	R Crutchfield
	20 APR 89	87.0 to 92.0	R. Crutchfield
	2 MAY 89	92.0 to 96.0	R. Crutchfield
	16 MAY 89	96.0 to 100.0	R. Crutchfield
	31 MAY 89	100.0 to 103.0	R. Crutchfield
	19 JUN 89	103.0 to 115 0	R Crutchfield
TBM Hole-through	13 JUL 89	115.0 to 118.6	R. Crutchfield

APPENDIX A

Photographs



View northeast across initial 12-foot deep excavation of San Pedro Creek Outlet Shaft. Rib and lagging collar in left background.

29 Jan 88 San Pedro Crk Tunnel Photo No. 1

View northeast into initial excavation for San Pedro Creek Outlet Shaft.

29 Jan 88 San Pedro Crk Tunnel Photo No. 2

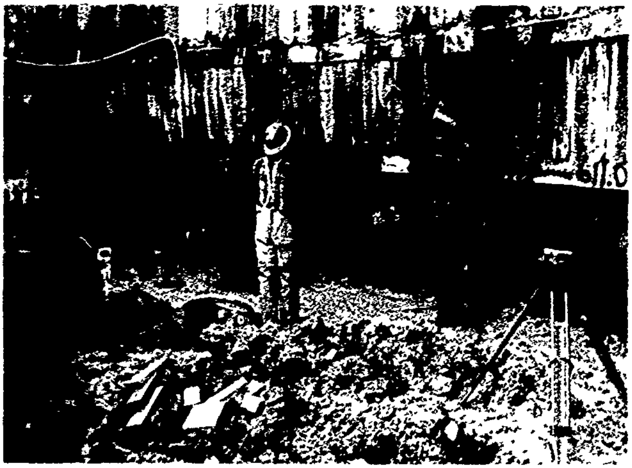
EXHIBIT 1

View southwest into San Pedro Crk Outlet Shaft to elevation 622, 17-foot depth.

9 Feb 88 San Pedro Crk Tunnel Photo No. 3

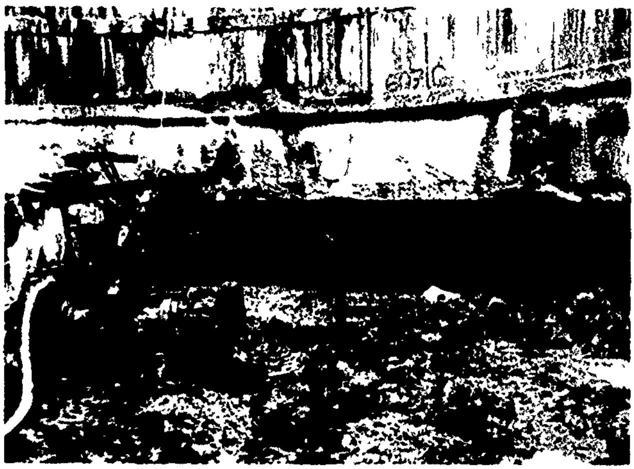
View southwest into San Pedro Crk Outlet Shaft to elevation 618. 21-foot depth. Alluvial ground-water inflow began at elevation 620.

12 Feb 88 San Pedro Crk Tunnel Photo No. 4



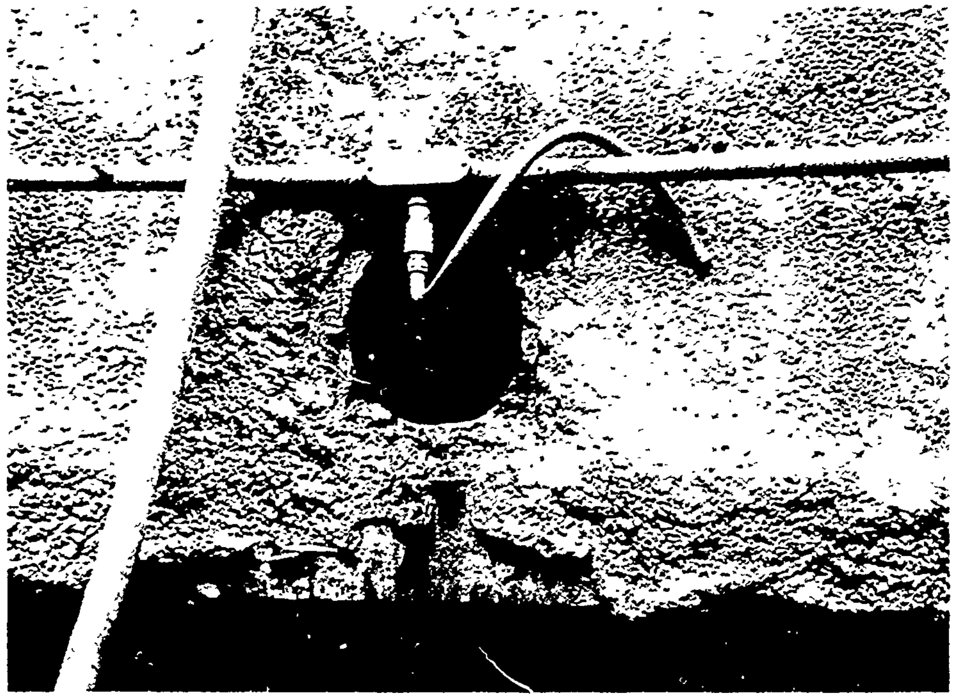
View northeast showing weathered clay shale between elevations 611 and 607 (32-foot depth) in San Pedro Crk Outlet Shaft.

23 Feb 88 San Pedro Crk Tunnel Photo No. 5



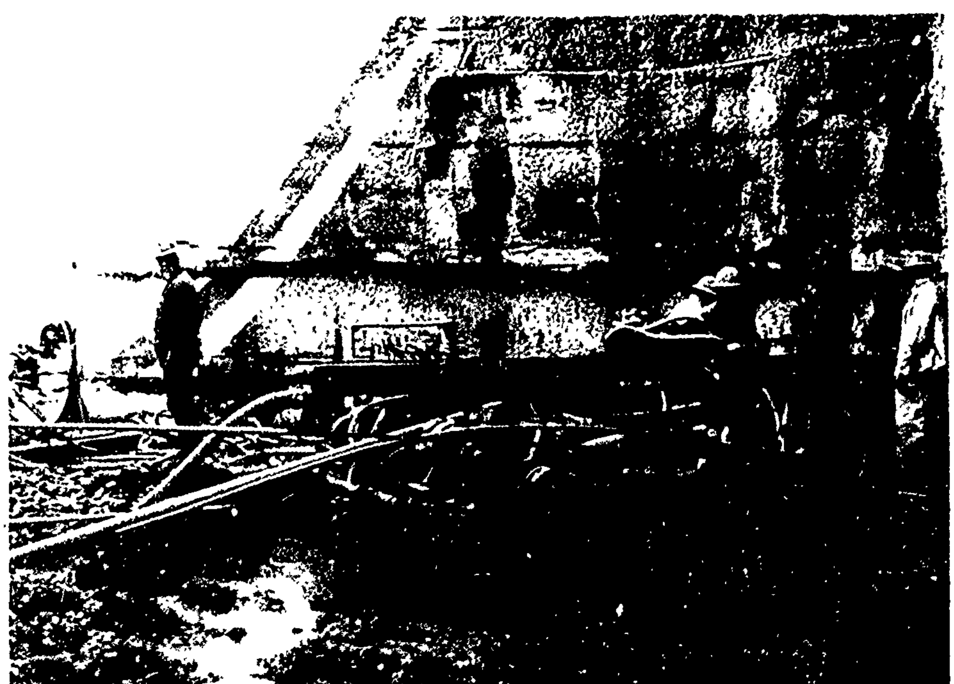
View southeast in San Pedro Crk Outlet Shaft showing the contact between weathered and unweathered clay shale at elevation 599, 40-foot depth.

2 Mar 88 San Pedro Crk Tunnel Photo No. 6



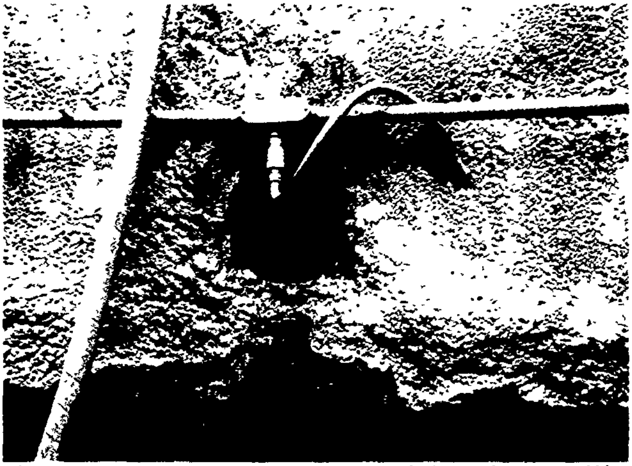
3-position extensometer, MPBX, installed at elevation 604, 35-foot depth, in San Pedro Creek Outlet Shaft.

3 Mar 88 San Pedro Crk Tunnel Photo No. 7



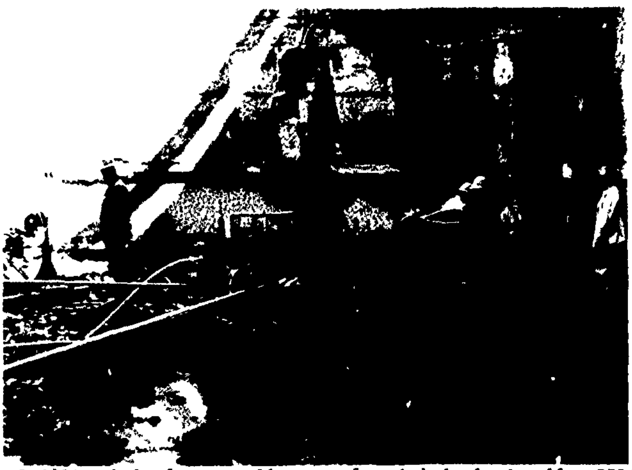
Drilling hole for installation of rock bolt load cell. RBLC, at elevation 596, 43-foot depth in San Pedro Creek Outlet Shaft.

18 Mar 88 San Pedro Crk Tunnel Photo No. 8



3-position extensometer, MPBX, installed at elevation 604, 35-foot depth, in San Pedro Creek Outlet Shaft.

3 Mar 88 San Pedro Crk Tunnel Photo No. 7



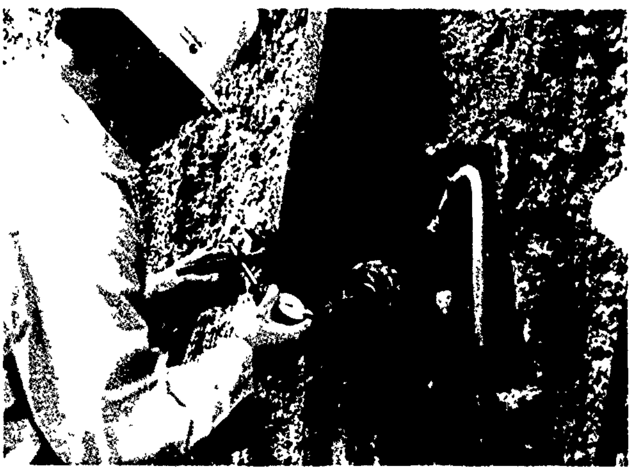
Drilling hole for installation of rock bolt load cell. RBLC, at elevation 596, 43-foot depth in San Pedro Creek Outlet Shaft.

18 Mar 88 San Pedro Crk Tunnel Photo No. 8

EXHIBIT 4

10-Ton pull-out test on rock bolt for load cell at elevation 596, 43-foot depth, in San Pedro Creek Outlet Shaft. Test by Woodward-Clyde Consultants.

18 Mar 88 San Pedro Crk Tunnel Photo No. 9



Close-up view of gauge to measure rock bolt movement in 10-Ton pull-out test shown above.

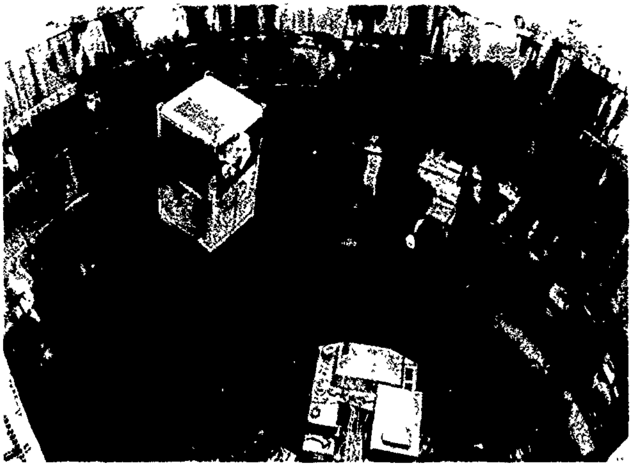
18 Mar 88 San Pedro Crk Tunnel Photo No. 10

Grouting alluvial aquifer through lagging in San Pedro Creek Outlet Shaft. Bottom of shaft at elevation 598, 41-foot depth.

9 Mar 88 San Pedro Crk Tunnel Photo No. 11

View northeast in San Pedro Creek Outlet Shaft showing soft, massive, unweathered clay shale between elevation 598 and 594, 41- to 45-foot depths.

16 Mar 88 San Pedro Crk Tunnel Photo No. 12



Man-cage being lowered by crane into San Pedro Creek Outlet Shaft, bottom of 49-foot depth.

25 Mar 88 San Pedro Crk Tunnel Photo No. 13

Geologist examining soft, massive, unctuous clay shale in the outlet shaft betwen elevation 594 and 590, 45- to 49-foot depths.

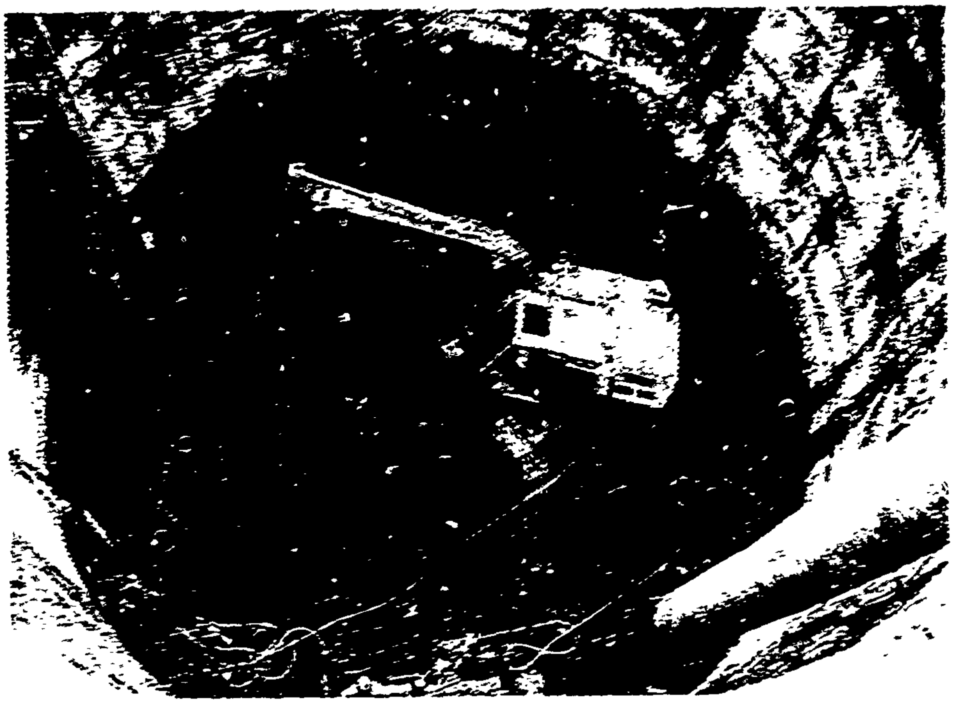
25 Mar 88 San Pedro Crk Tunnel Photo No. 14

Concrete delivered for shotcreting in San Pedro Creek Outlet Shaft.

25 Mar 88 San Pedro Crk Tunnel Photo No. 15

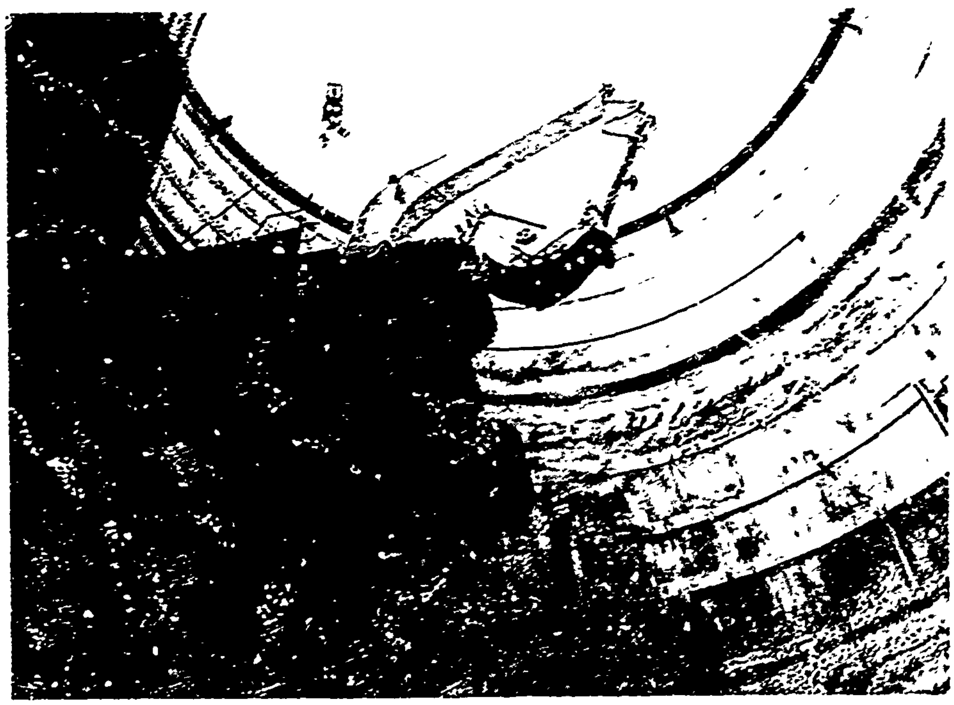
Application of 8 inches of shotcrete over two layers of wire mesh as primary support at elevation 590, 49-foot depth in outlet shaft.

25 Mar 88 San Pedro Crk Tunnel Photo No. 16



View southwest into outlet shaft showing backhoe excavation at elevation 585, 54-foot depth.

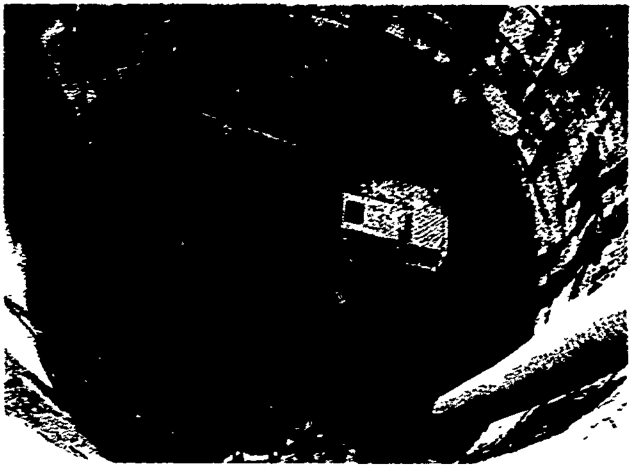
29 Mar 88 San Pedro Crk Tunnel Photo No. 17



View of backhoe being hoisted out of outlet shaft from elevation 576, 63-foot depth.

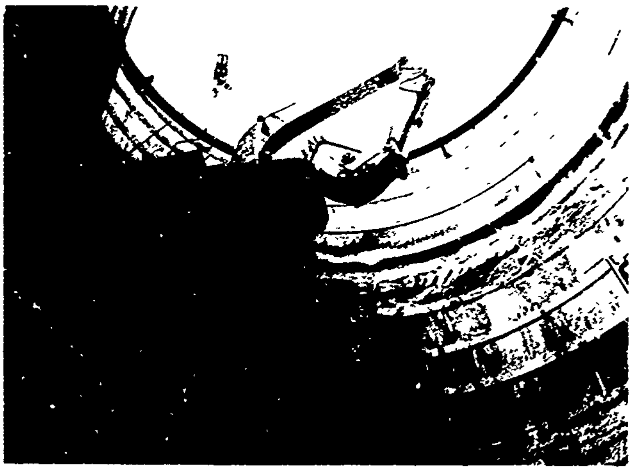
5 Apr 88 San Pedro Crk Tunnel Photo No. 18

EXHIBIT 9



View southwest into outlet shaft showing backhoe excavation at elevation 585, 54-foot depth.

29 Mar 88 San Pedro Crk Tunnel Photo No. 17



View of backhoe being hoisted out of outlet shaft from elevation 576, 63-foot depth.

5 Apr 88 San Pedro Crk Tunnel Photo No. 18

View southeast in outlet shaft showing soft, massive, unctuous clay shale between elevation 585 and 581, 54- to 58-foot depths.

1 Apr 88 San Pedro Crk Tunnel Photo No. 19

View northeast along southeast wall of outlet shaft showing close-up of the clay shale at the 54- to 58-foot depth.

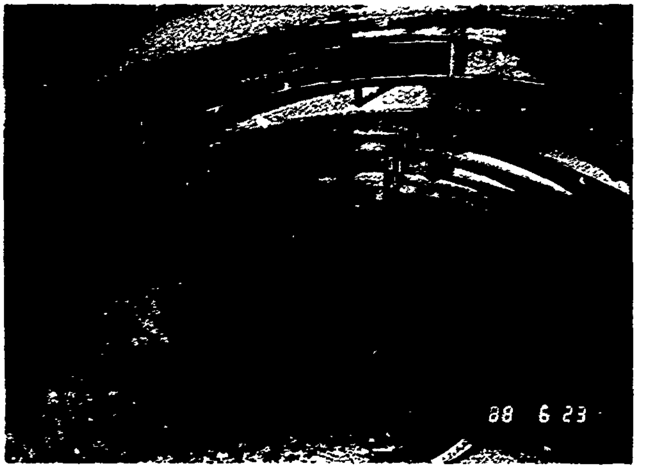
1 Apr 88 San Pedro Crk Tunnel Photo No. 20

Testing support rock bolts at elevation 557 on east side of San Pedro Creek Outlet Shaft.

5 Jun 88 San Pedro Crk Tunnel Photo No. 21

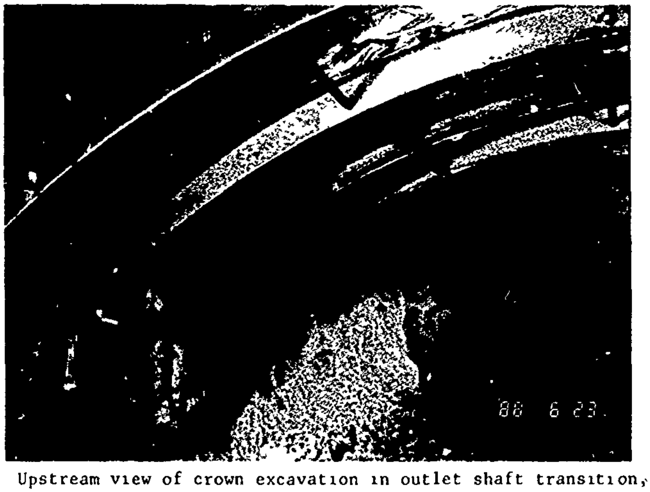
Roadheader beginning excavation of horizontal transition from outlet shaft to tunnel at elevation 533 to 522, 106- to 117-foot depth.

13 Jun 88 San Pedro Crk Tunnel Photo No. 22



View upstream of transition crown excavation in outlet shaft, showing Ribs E to P.

23 Jun 88 San Pedro Cr' Tunnel Photo No. 23

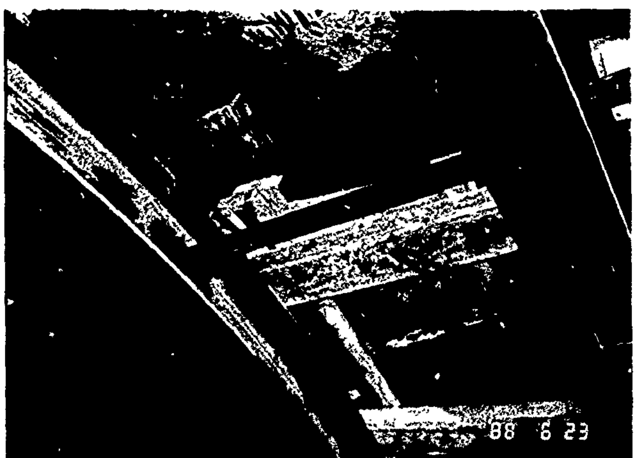


Upstream view of crown excavation in outlet shaft transition, showing Ribs D to P.

23 Jun 88 San Pedro Crk Tunnel Photo No. 24

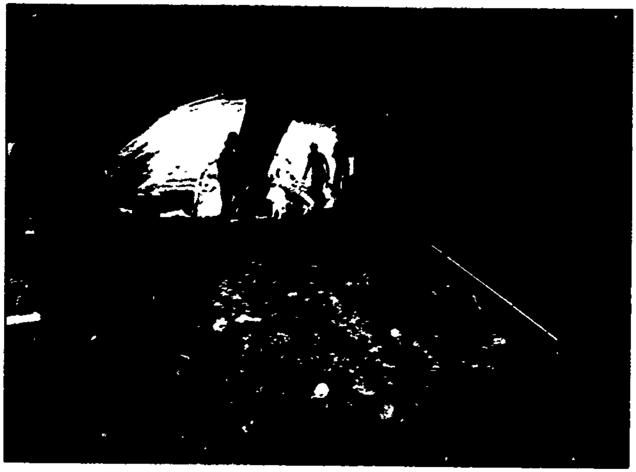
View of west side of crown excavation in outlet shaft transition, showing Ribs E to J.

23 Jun 88 San Pedro Crk Tunnel Photo No. 25



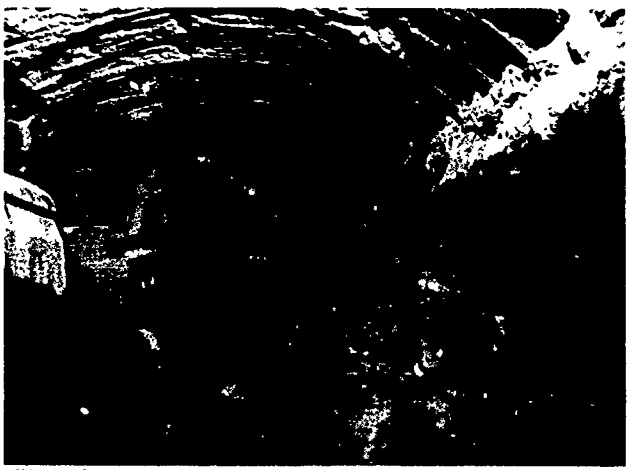
Cribbing support above Ribs I and J where 6'x3'x.5' slab of rock fell from crown.

23 Jun 83 San Pedro Crk Tunnel Photo No. 26



View of steel rib and shotcrete supported crown of outlet shaft transition after vertical shaft excavated another 5 feet to elevation 517.

1 Jul 88 San Pedro Crk Tunnel Photo No. 27



View of backhoe center notch excavation to springline in outlet shaft transition.

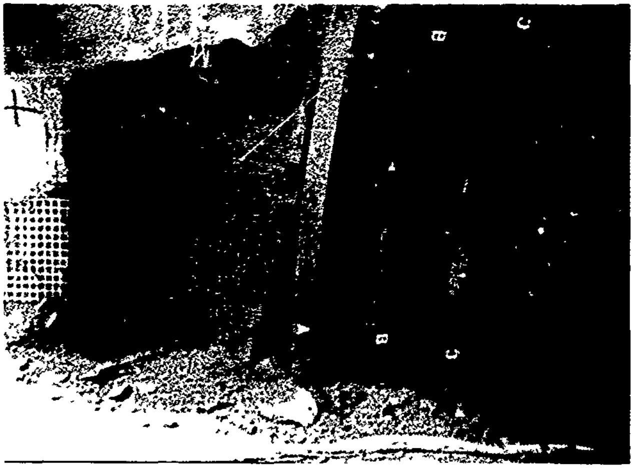
11 Jul 88 San Pedro Crk Tunnel Photo No. 28

Roadheader in San Pedro Creek Outlet Shaft in preparation to excavate for setting transition ribs to springline, elevation 511.6.

12 Jul 88 San Pedro Crk Tunnel Photo No. 29

Roadheader excavation to springline at Rib F on west side of outlet transition.

12 Jul 88 San Pedro Crk Tunnel Photo No. 30



View northwest of outlet shaft transition excavated to springline, elevation 511.6

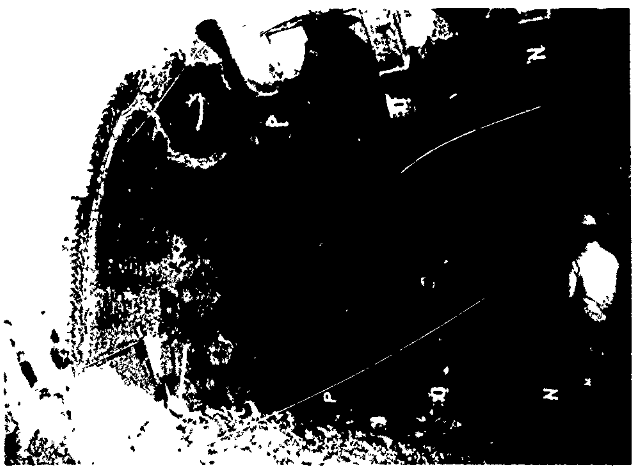
12 Jul 88 San Pedro Crk Tunnel Photo No. 31

View of roadheader cut to springline at Rib F on west side of outlet transition. Note shallow desiccation fractures in center photo.

12 Jul 88 San Pedro Crk Tunnel Photo No. 32

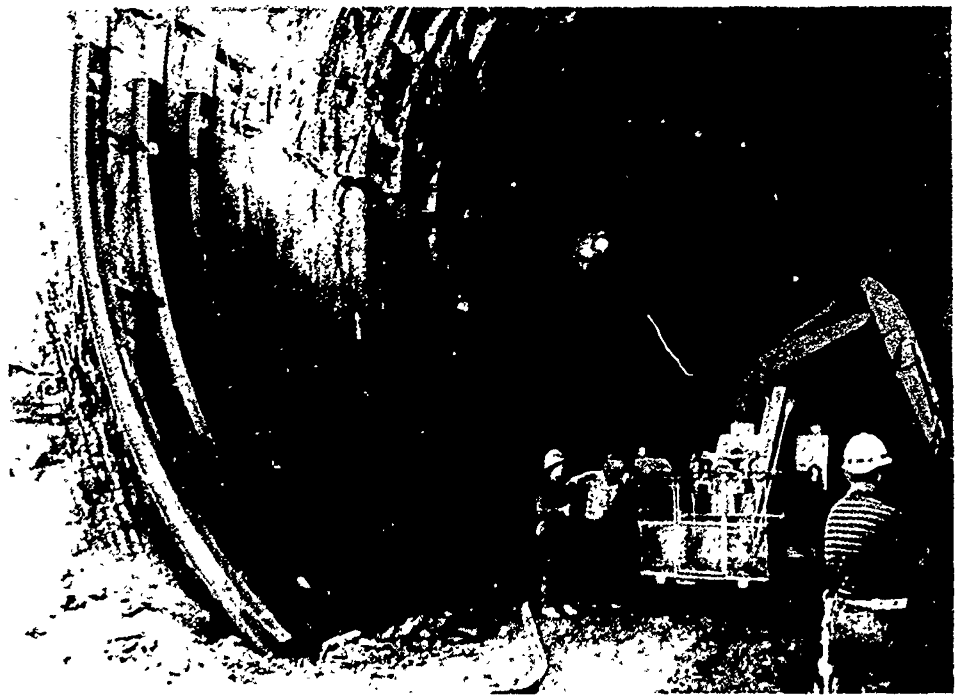
View northeast of outlet shaft transition excavated to springline, showing Ribs K to P. Excavation in soft to moderately soft, massive clay shale.

20 Jul 88 San Pedro Crk Tunnel Photo No. 33



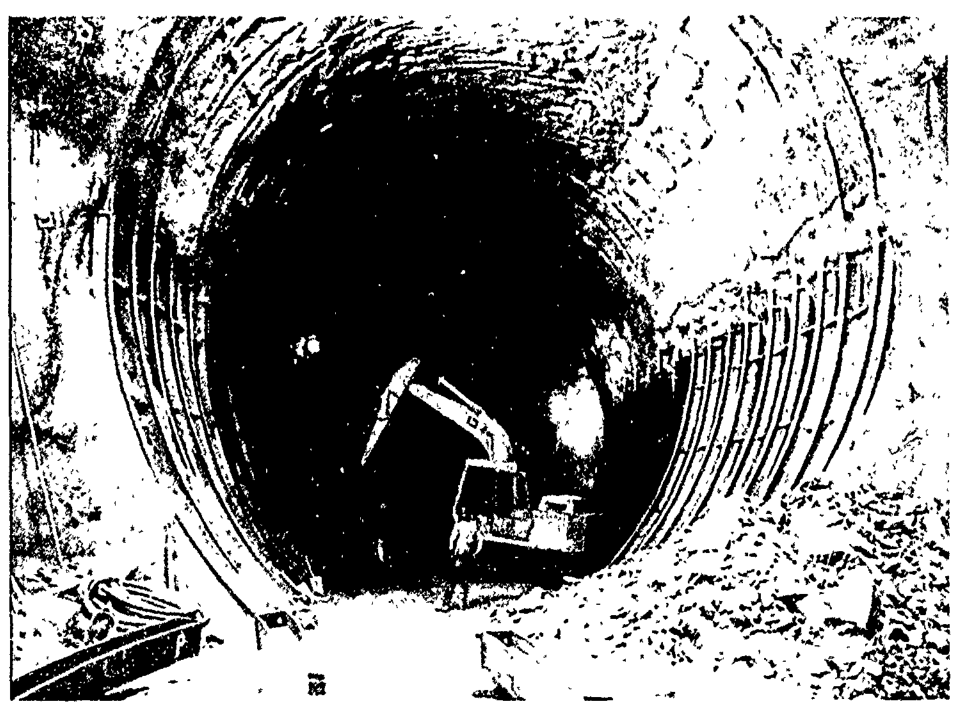
View of tunnel end of outlet shaft transition excavated to springline, elevation 511.6.

20 Jul 88 San Pedro Crk Tunnel Photo No. 34



View north of outlet shaft transition excavated to invert, elevation 490. Some fracturing in lower 10 feet of excavation.

10 Aug 88 San Pedro Crk Tunnel Photo No. 35

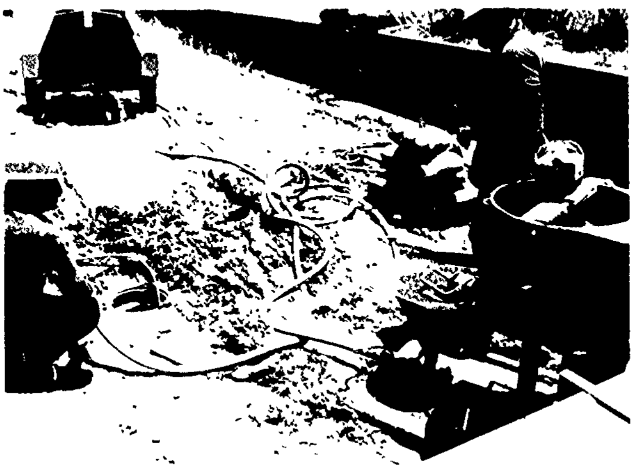


View upstream along fully excavated outlet shaft transition, 60 feet in length.

12 Aug 88 San Pedro Crk Tunnel Photo No. 36

View southwest of drilling of vent shaft at Station 158+14 near Durango Street.

13 May 88 San Pedro Crk Tunnel Photo No. 37



View northeast of grouting of anchor rods for 6-position extensometer at Station 158+47 near Durango Street.

19 Jul 88 San Pedro Crk Tunnel Photo No. 38

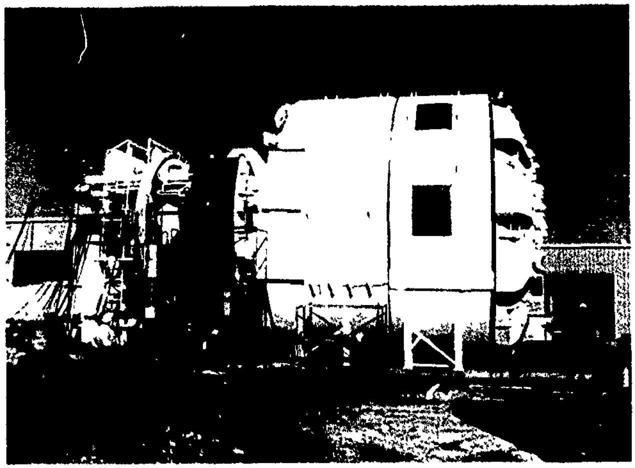
View south of Beck Foundation Company drilling maintenance shaft through upper ring of concrete soldier piers.

14 Jul 88 San Pedro Crk Tunnel Photo No. 39

Drilling of maintenance shaft with 6-foot diameter pilot bore and reaming blades to full diameter of 22 feet, 4 inches.

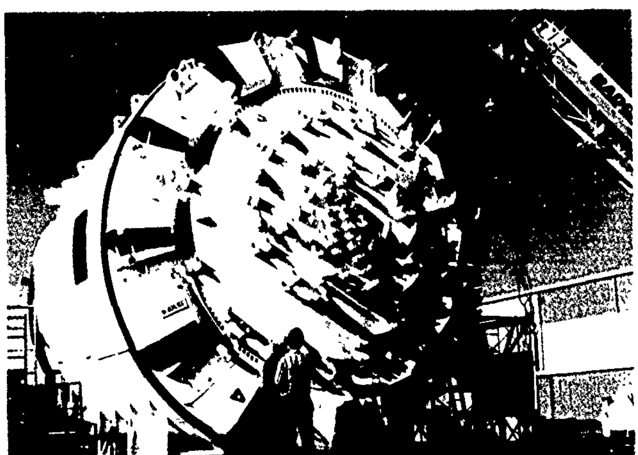
14 Jul 88 San Pedro Crk tunnel Photo No. 40

EXHIBIT 20



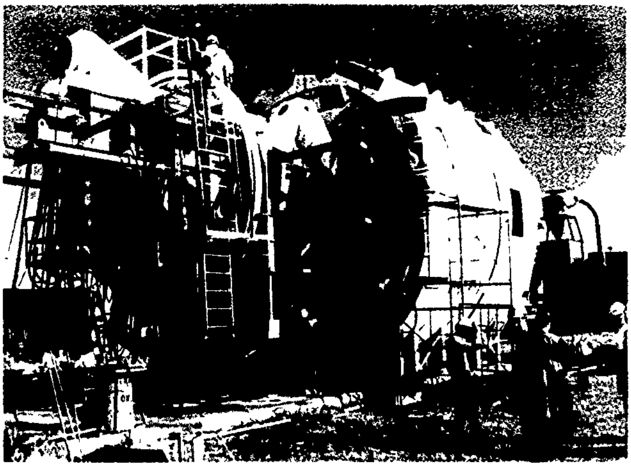
Modified Robbins Model 243-217 tunnel boring machine, TBM, at Boretec, Inc. work yard, 5797 Dietrich Road, San Antonio, TX.

27 Sep 88 San Pedro Crk Tunnel Photo No. 41



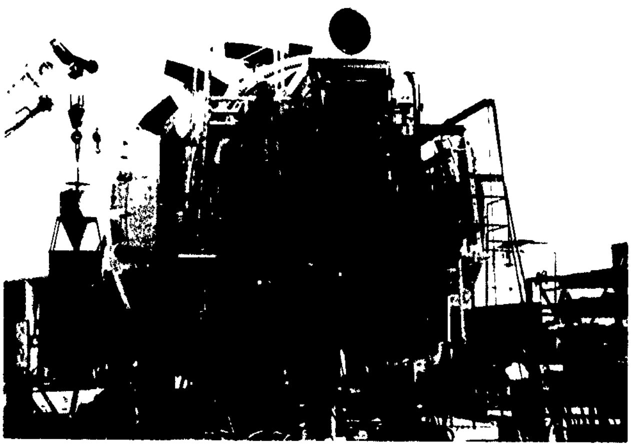
TBM as modified by Boretec from hard rock machine to soft rock machine (26' 11" dia).

27 Sep 88 San Pedro Crk Tunnel Photo No. 42



View of back of TBM showing gripper pad on right side and liner erector to the right of the ladder.

27 Sep 88 San Pedro Crk Tunnel Photo No. 43

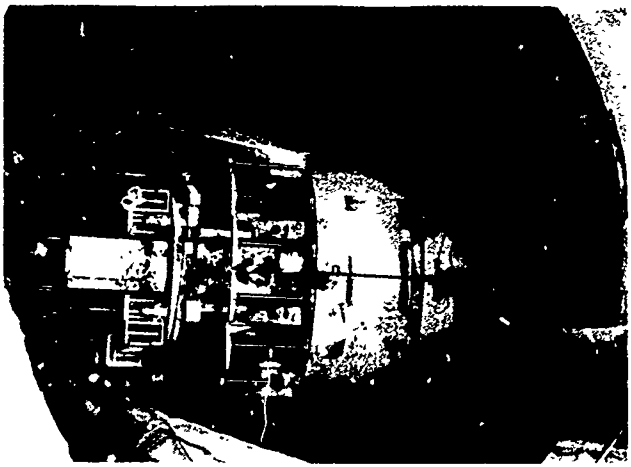


Rearview of TBM being renovated and modified after shipment from the Kerckhoff 2 Tunnel near Fresno, California.

27 Sep 88 San Pedro Crk Tunnel Photo No. 44

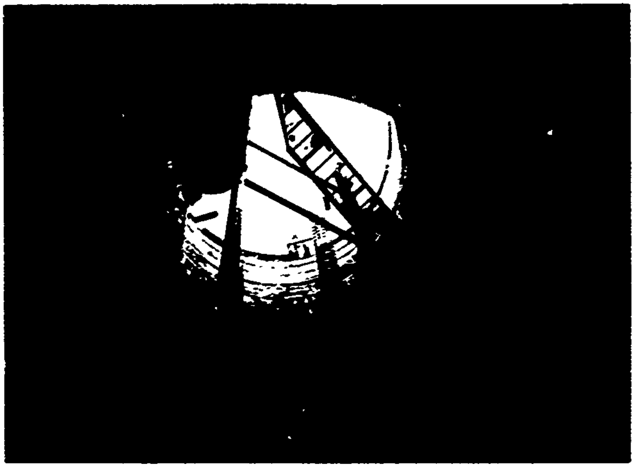
View of TBM being reassembled in San Pedro Creek Outlet Shaft.

2 Nov 88 San Pedro Crk Tunnel Photo No. 45



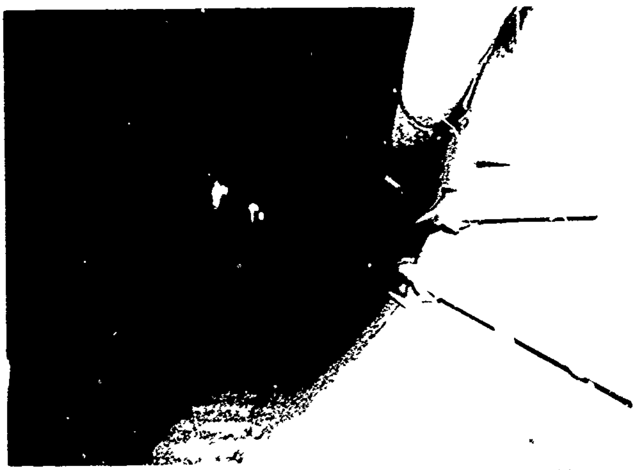
TBM parts were transported from Boretec yard and re-assembled in outlet shaft.

2 Nov 88 San Pedro Crk Tunnel Photo No. 46



Installation of supporting frame for muck elevator in San Pedro Creek Outlet Shaft.

3 Jan 89 San Pedro Crk Tunnel Photo No. 47



View upstream into first curve from about Station 144+50 in San Pedro Creek Tunnel.

9 Feb 89 San Pedro Crk Tunnel Photo No. 48

Grout batching in outlet shaft for backpack grouting of tunnel liner.

1 Mar 89 San Pedro Crk Tunnel Photo No. 49

Batching of neat cement grout at a 1:1 water to cement ratio by volume.

1 Mar 89 San Pedro Crk Tunnel Photo No. 50

View upstream at grouting jumbo at about tunnel Station 145+00.

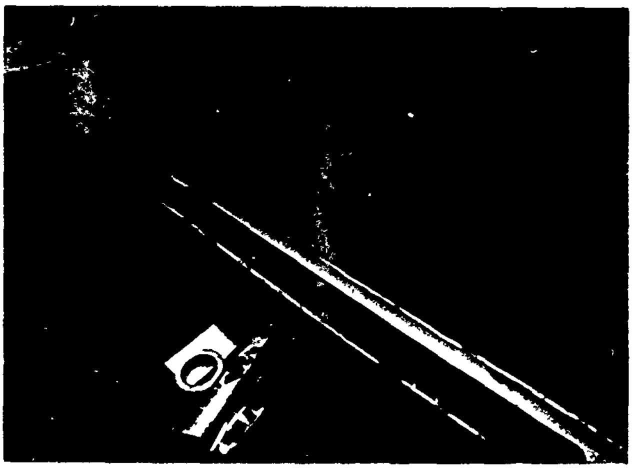
1 Mar 89 San Pedro Crk Tunnel Photo No. 51

View downstream toward outlet shaft from top of grouting jumbo at about Station 145+00.

1 Mar 89 San Pedro Crk Tunnel Photo No. 52

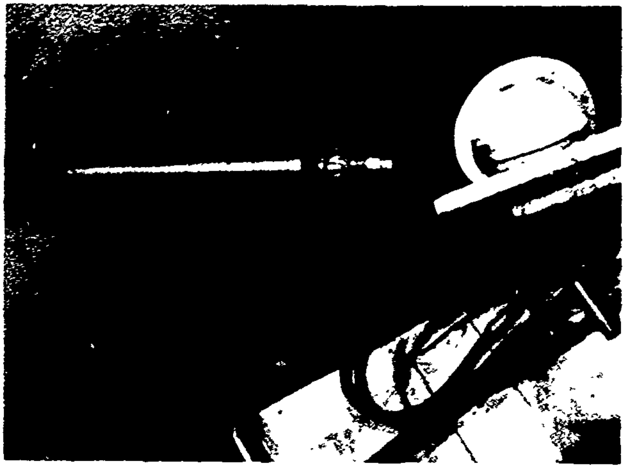
Drilling borescope hole B-5 through TBM tail shield at tunnel Station 143+71.

28 Dec 88 San Pedro Crk Tunnel Photo No. 53



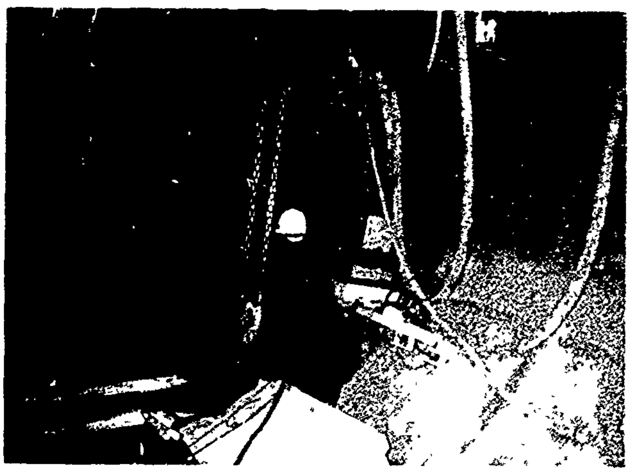
Core sample of clay shale taken from borescope hole B-6 at tunnel Station 143+71. Borescope holes were drilled to a depth of about 8 feet.

28 Dec 88 San Pedro Crk Tunnel Photo No. 54



Borescope observation for stress relief fractures in hole B-5 at tunnel Station 143+71.

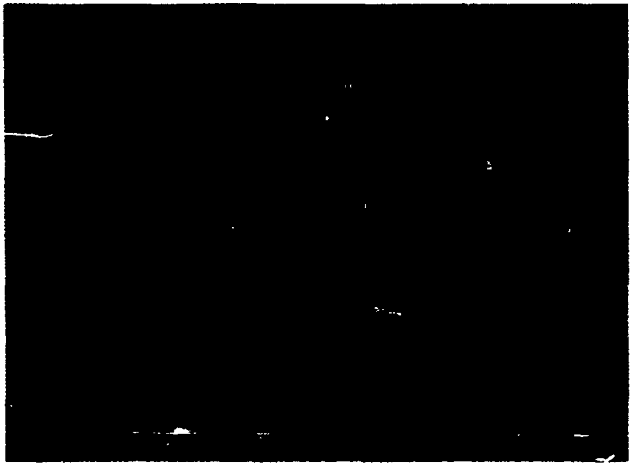
28 Dec 88 San Pedro Crk Tunnel Photo No. 55



Down-hole video taping borescope holes at tunnel Station 158+39.

22 Mar 89 San Pedro Crk Tunnel Photo No. 56

EXHIBIT 28



View of precast liner segments prepared for erection at back of TBM at Station 157+38.

16 Mar 89 San Pedro Crk Tunnel Photo No. 57

View downstream along TBM trailing gear. Muck car being loaded in background.

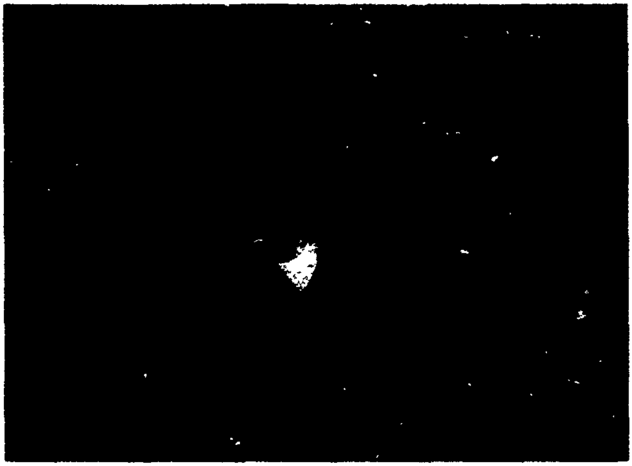
16 Mar 89 San Pedro Crk Tunnel Photo No. 58

Upward view through TBM trailing gear at Station 158+14
vent shaft intersection in tunnel crown.

20 Mar 89 San Pedro Crk Tunnel Photo No. 59

Wood lagging and W6x20 steel sets in tunnel crown at
Station 158+14 vent shaft intersection.

20 Mar 89 San Pedro Crk Tunnel Photo No. 60



Abandoned water well intersected by TBM at tunnel Station 178+49. Well was partially plugged but produced a steady flow of 2 gpm.

17 May 89 San Pedro Crk Tunnel Photo No. 61

Abandoned water well at Station 178+49 prepared for grouting.

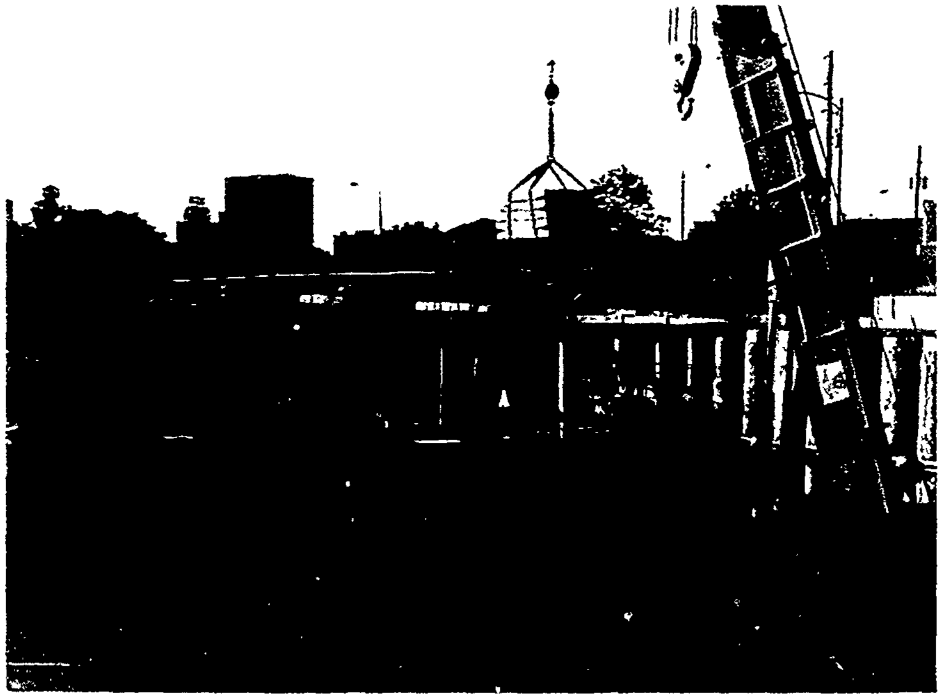
17 Oct 89 San Pedro Crk Tunnel Photo No. 62

View upstream toward grout batching plant at Station 158+14, vent shaft location.

17 May 89 San Pedro Crk Tunnel Photo No. 63

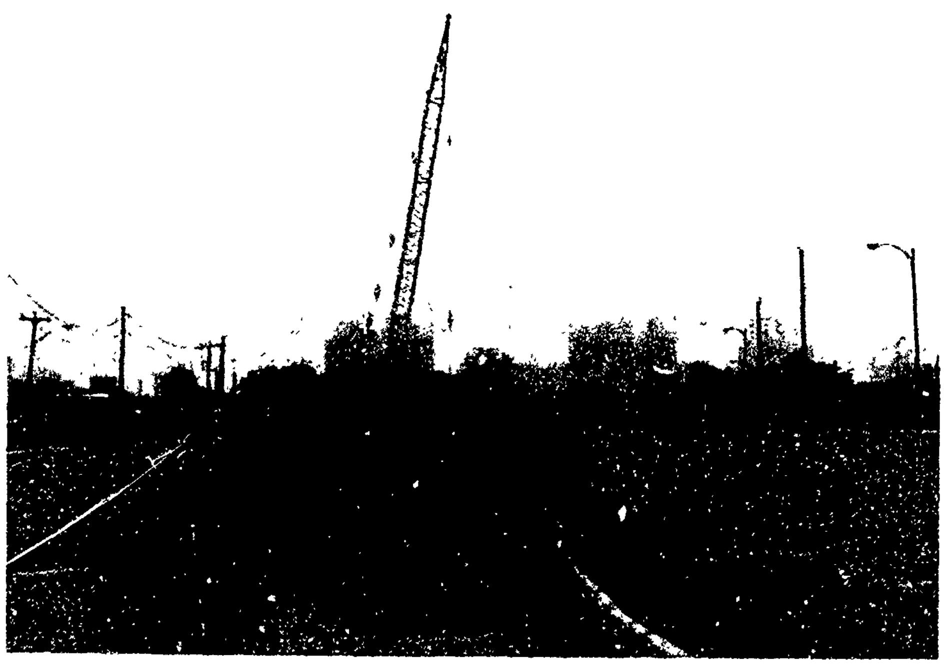
View downstream toward outlet shaft in background.

17 May 89 San Pedro Crk Tunnel Photo No. 64



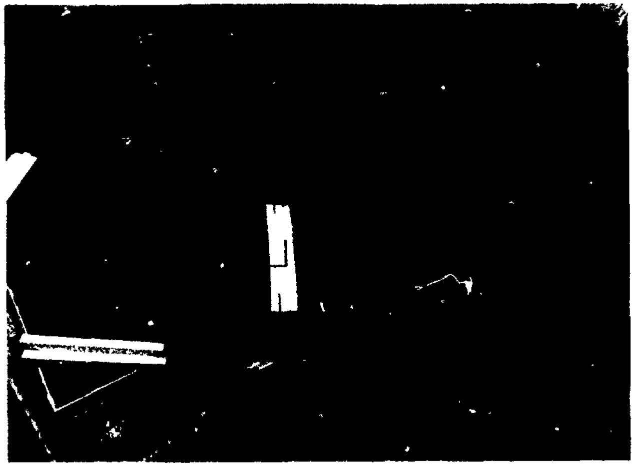
View south at construction of water protection cell to prevent flooding of inlet shaft excavation.

3 Oct 88 San Pedro Crk Tunnel Photo No. 65



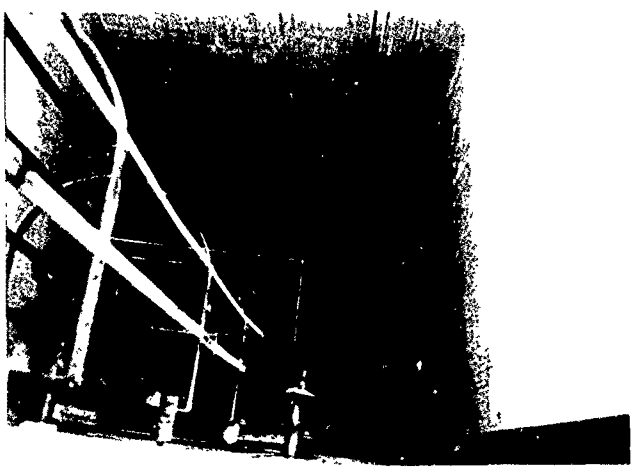
View southeast at San Pedro Creek Inlet Shaft surrounded by water protection cell.

2 Nov 88 San Pedro Crk Tunnel Photo No. 66



Excavation of upper 21 feet of inlet shaft and reinforcement for rhombus shaped concrete temporary surface structure.

2 Nov 88 San Pedro Crk Tunnel Photo No. 67



View into inlet shaft from northeast wall. Bottom of excavation at elevation 583, 40-foot depth.

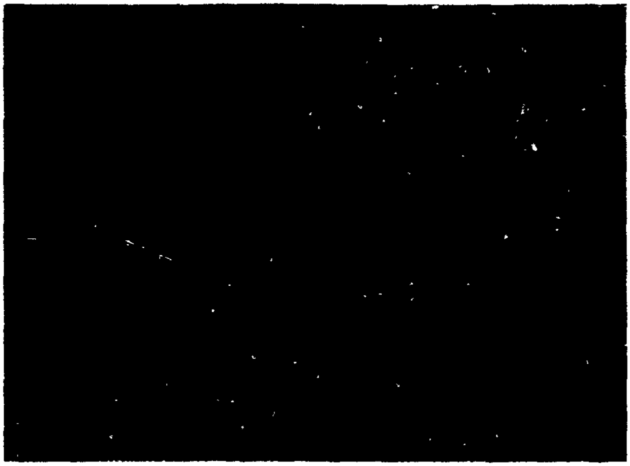
25 Jan 89 San Pedro Crk Tunnel Photo No. 68

View northwest in inlet shaft showing very limy, moderately hard to hard, clay shale of the M-3 Stratigraphic Marker Bed. The bottom of the concrete is at the top of the M-3 bed, elevation 583.

2 Feb 89 San Pedro Crk Tunnel Photo No. 69

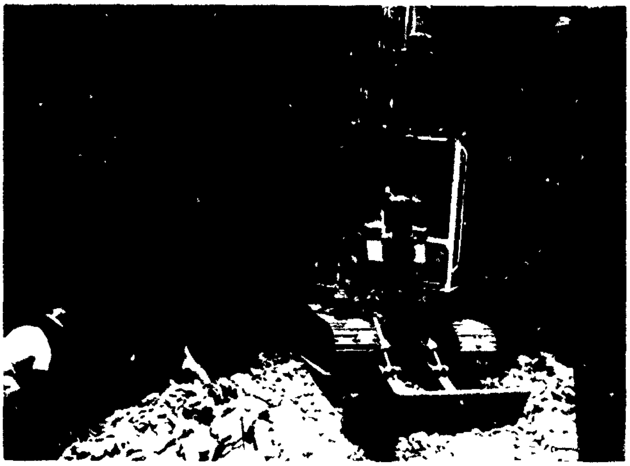
View northwest in inlet shaft showing moderately hard to hard, massive, very limy clay shale between elevations 556 and 552, 67- to 71-foot depth.

7 Mar 89 San Pedro Crk Turnel Photo No. 70



View southwest in inlet shaft excavated to elevation 536, 87-foot depth. Upper rock is very limy and harder than the less limy rock in the lower photo.

31 Mar 89 San Pedro Crk Tunnel Photo No. 71



View southeast toward inlet shaft undercut for tunnel intersection. Shaft excavated to elevation 527, 96-foot depth.

2 May 89 San Pedro Crk Tunnel Photo No. 72

TBM hole-through in San Pedro Creek Inlet Shaft.

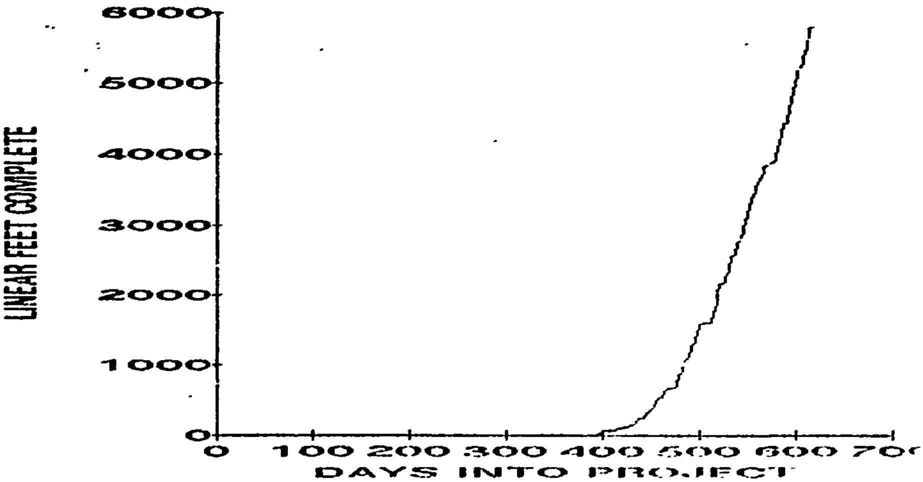
13 Jul 89 San Pedro Crk Tunnel Photo No. 73

APPENDIX B

Tunneling Progress Charts

SAN PEDRO CREEK TUNNEL

PROGRESS CHART AS AT 17 JULY 89



Notes: 1. Day 490 was 7 Mar 89 - Scheduled Completion Date.
2. The San Pedro Creek Tunnel is 5843 feet long.
3. Hole through was at 1805 hours on 13 Jul 89.
4. Tunnel excavation was completed on 17 Jul 89.

MACHINE DATA

Manufactured By: ROBBINS.
Model: 243-217/Modified.
Weight: 550 tons.
Length: 38 feet.
Thrust: 2,640,000 lbs.
Cutters: 57 Discs, 2 Bi-Discs in Centre. Pick option.
Rotation By: Ten 200 HP, 460 V AC Motors.
Guidance: Laser Beam.
Waste Disposal: Trailing Conveyor & Train.

PROGRESS

Average: 30 ft per working day.
Target : 60 ft per working day.

CONTRACT DATA

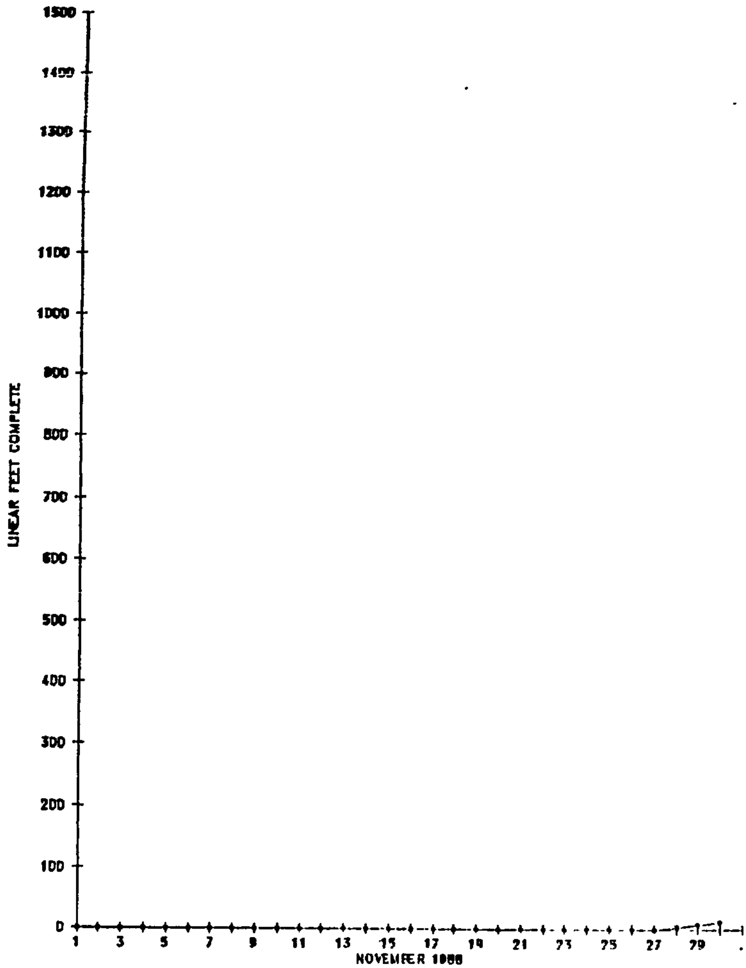
Contractor : OHBAYASHI CORPORATION
South San Francisco

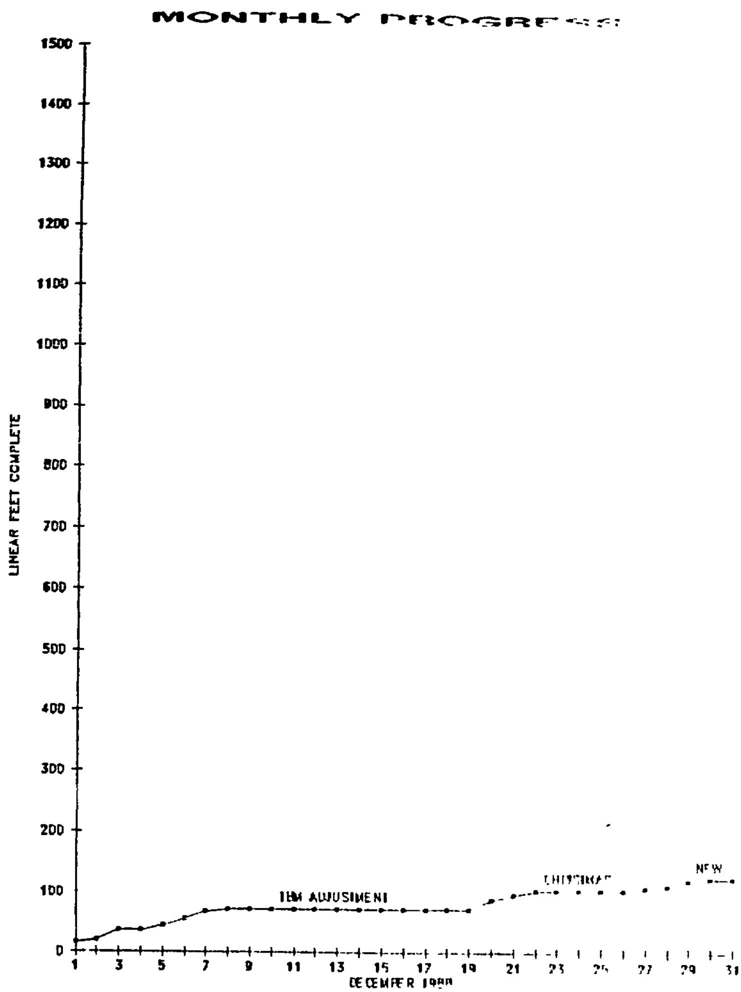
Contract No : DACW63-87-C-0109

Bid : $47,750,000.40

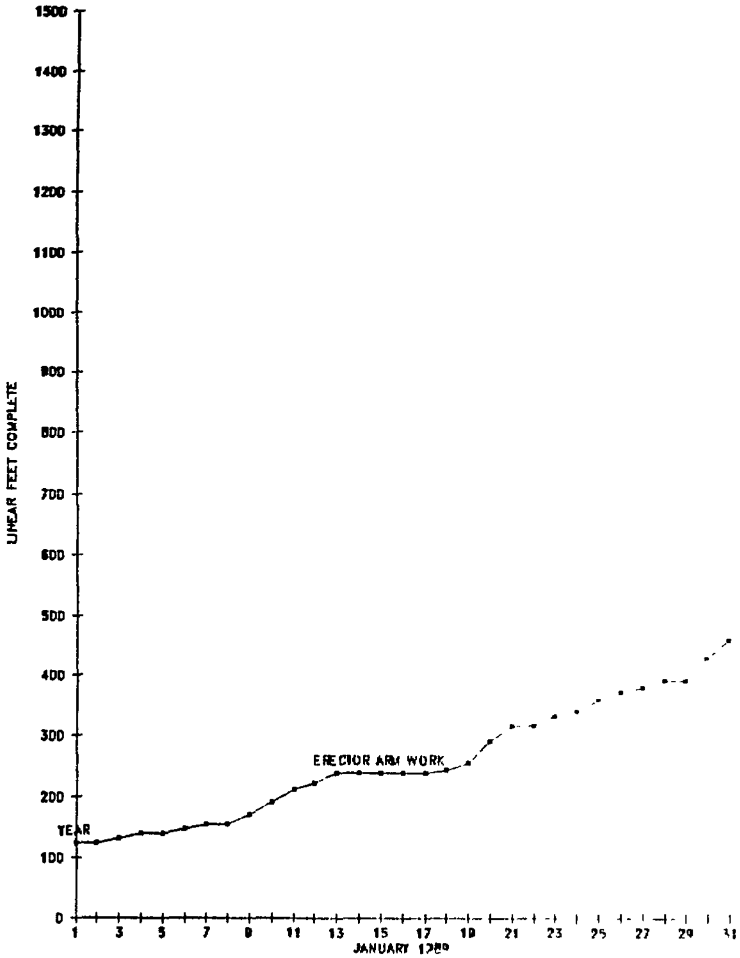
Acknowledged: 3 Nov 87

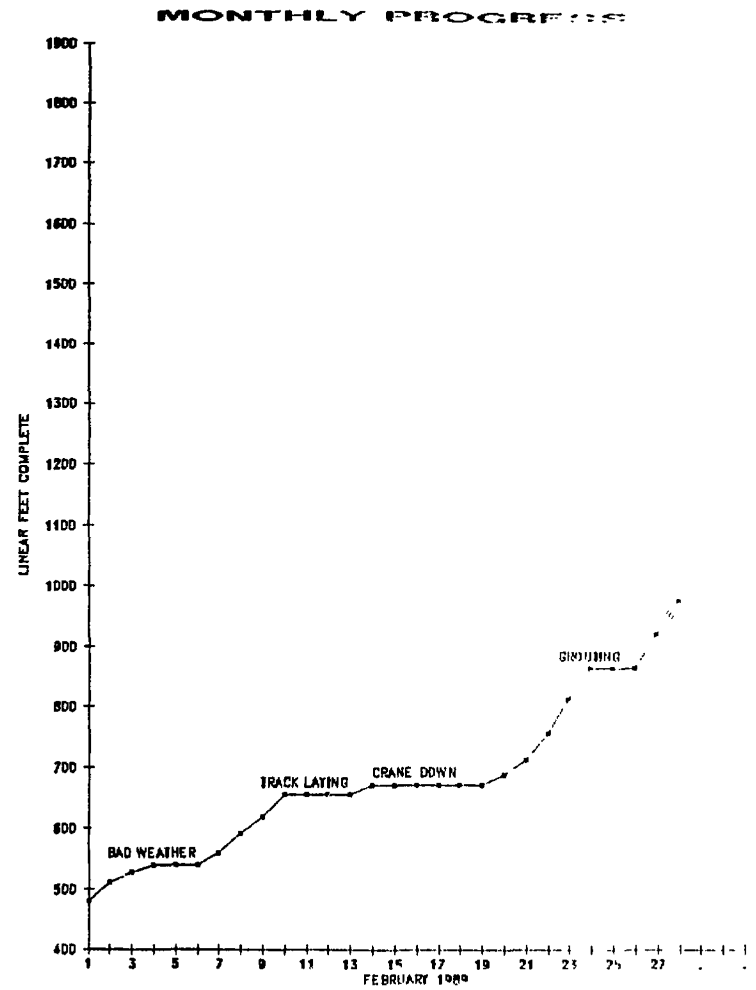
MONTHLY PROGRESS



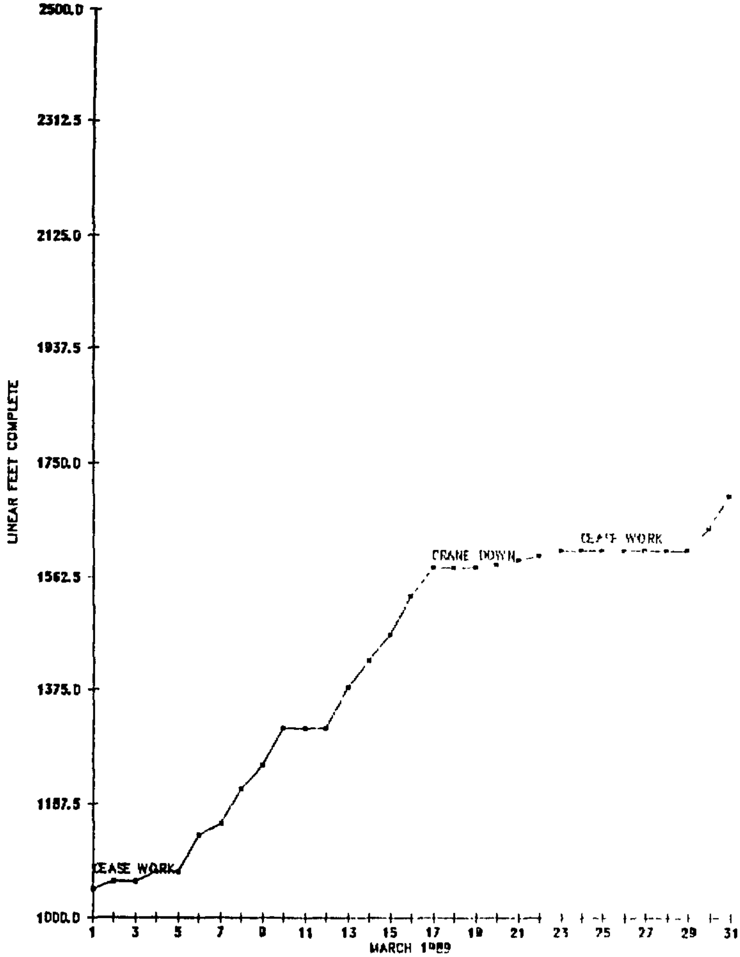

MONTHLY
LINEAR FEET COMPLETE
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
1
3
5
7
9
11
13
15
17
19
21
NEW

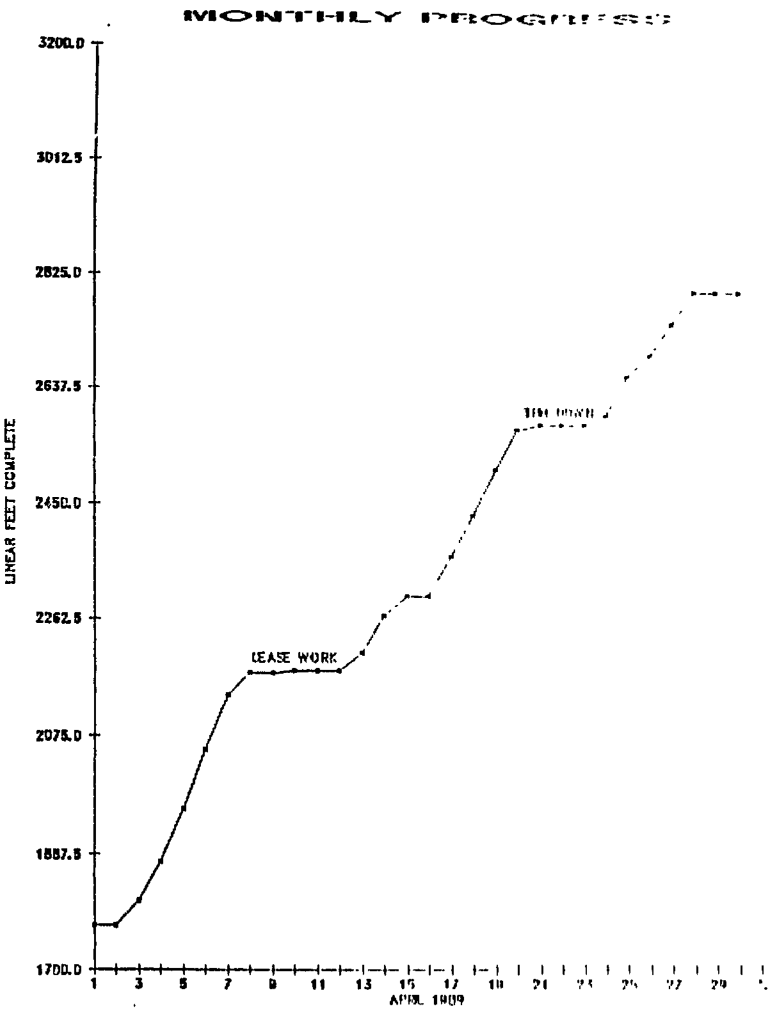
MONTHLY PROGRESS



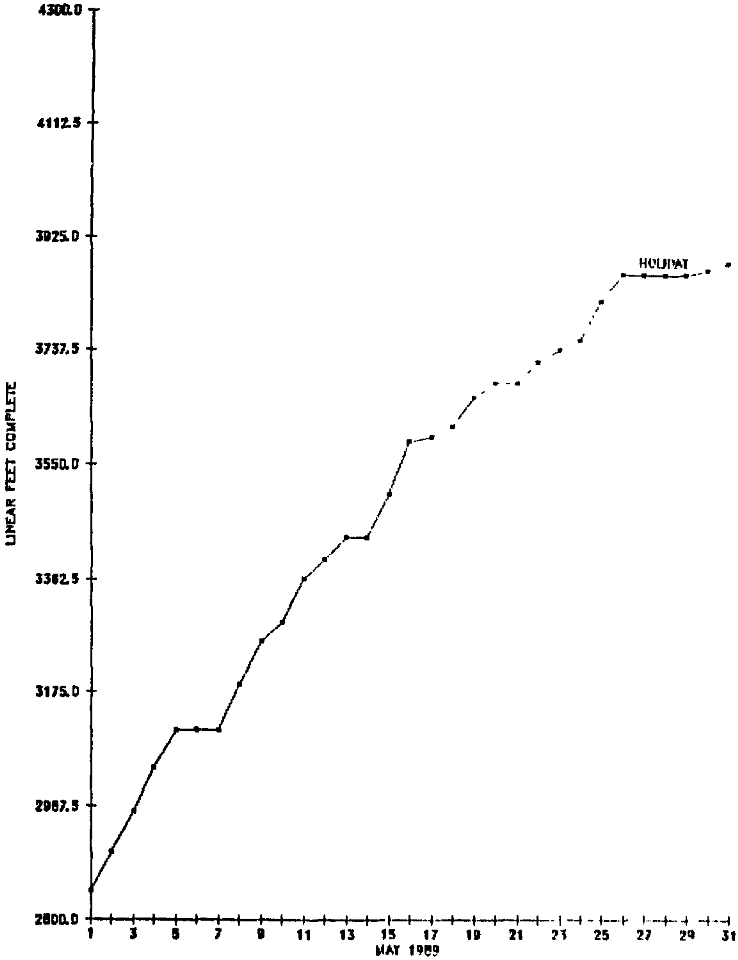

MONTHLY PROGRESS
LINEAR FEET COMPLETE
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
BAD WEATHER
TRACK LAYING
CRANE DOWN
GROUTING
1
3
5
7
9
11
13
15
17
19
21
23
25
27
FEBRUARY 1989

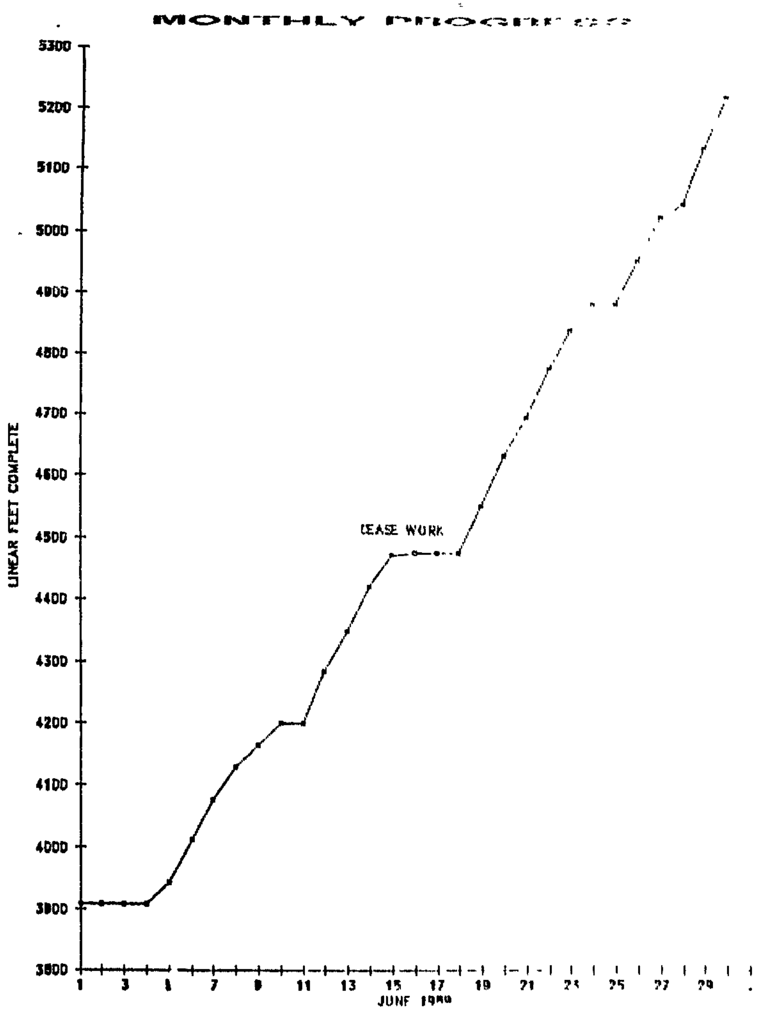
MONTHLY PROGRESS

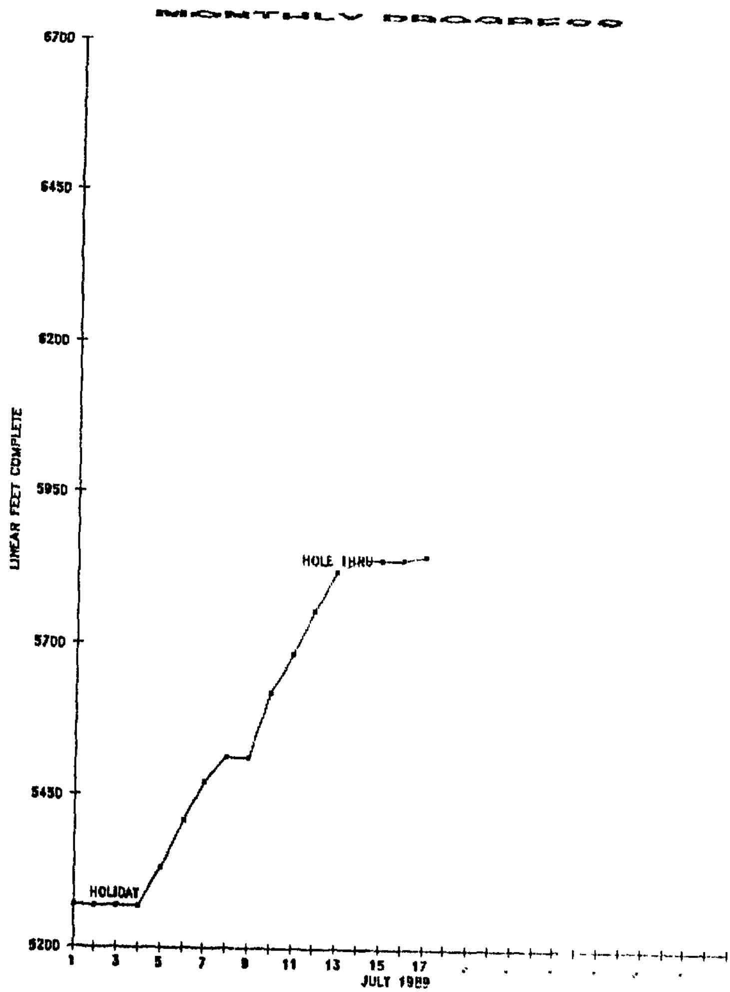



MONTHLY PROGRESS
LINEAR FEET COMPLETE
3200.0
3012.5
2825.0
2637.5
2450.0
2262.5
2075.0
1887.5
1700.0
LEASE WORK
1
3
5
7
9
11
13
15
17

MONTHLY PROGRESS




MONTHLY
LINEAR FEET COMPLETE
5300
5200
5100
5000
4900
4800
4700
4600
4500
4400
4300
4200
4100
4000
CEASE WORK
1
3
7
11
13
15
17
19
21
25
JUNE



MONTHLY PROGRESS
6700
6450
6200
5950
5700
5450
5200
LINEAR FEET COMPLETE
HOLE THRU
HOLIDAY
1
3
5
7
9
11
13
15
17
JULY 1989

APPENDIX C

Tunnel Liner Grouting Data

PEA GRAVEL AND GROUT CONSUMPTION – S[illegible] TUNNEL

		Pea Gravel			Grout	
Week End	Rings Placed	Delivered tons	Delivered cu ft	Per Ring cu ft/ring	Delivered bags=cu ft	Per Ring cu ft/ring
Dec 4	9	0	0	0	0	0
Dec 11	9	109	2291	255	0	0
Dec 18	0	0	0		0	
Dec 25	8	39	821	103	0	0
Jan 1	5	0	0	0	0	0
Jan 8	8	42	881	111	0	0
Jan 15	21	64	1347	61	0	0
Jan 22	19	63	1326	70	0	0
Jan 29	19	42	884	47	0	0
Feb 5	37	81	1705	16	0	0
Feb 12	29	84	1768	61	300	10
Feb 19	4	41	863	216	465	116
Feb 26	48	42	881	18	585	12
Mar 5	53	201	4231	80	779	15
Mar 12	59	191	4021	68	699	12
Mar 19	67	65	1368	20	966	11
Mar 26	7	0	0	0	3159	191
Apr 2	41	124	2610	61	1330	106
Apr 9	101	123	2589	26	1811	18
Apr 16	31	0	0	0	1286	138
Apr 23	69	131	2758	40	3772	55
Apr 30	55	0	0	0	812	15
May 7	79	138	2905	37	2109	27
May 14	80	231	4863	61	3231	10
May 21	63	215	4526	72	1291	68
May 28	46	61	1281	28	1100	21
Jun 4	10	0	0	0	0	0
Jun 11	73	214	4505	62	3279	15
Jun 18	69	130	2737	10	1641	21
Jun 25	102	211	5073	50	2156	21

TABLE 1 : WEEKLY DATA

		Pea Gravel		Grout	
Month	Rings Placed	Delivered cu ft	Per Ring cu ft/ring	Delivered bags=cu ft	Per Ring cu ft/ring
27 Nov – 1 Jan	31	3115	100	0	0
2 Jan – 29 Jan	67	4442	66	0	0
30 Jan – 26 Feb	118	5220	44	1350	11
27 Feb – 2 Apr	227	12230	54	10233	15
3 Apr – 30 Apr	256	5317	21	10711	12
1 May – 28 May	268	13577	51	10737	10
29 May – 25 Jun	254	12311	18	7066	28
TOTALS:	1221	56216	46	40097	36 (1)

TABLE 2 : MONTHLY DATA

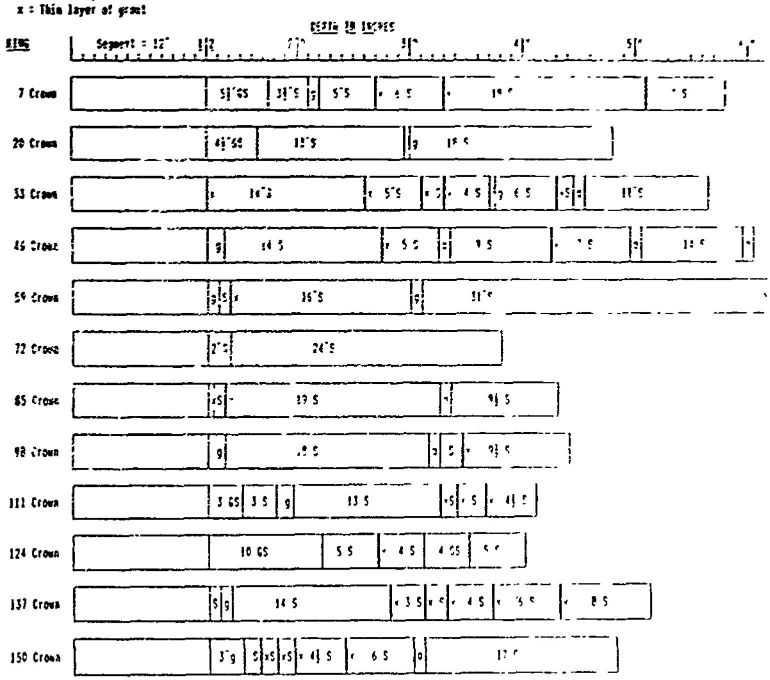
NOTE: 1. The average grout figure assumes 1100 rings fully grouted.

INSPECTION OF LINER GROUTING

CORES TAKEN FROM SAN PEDRO TUNNEL

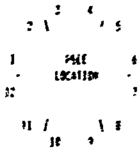
LEGEND

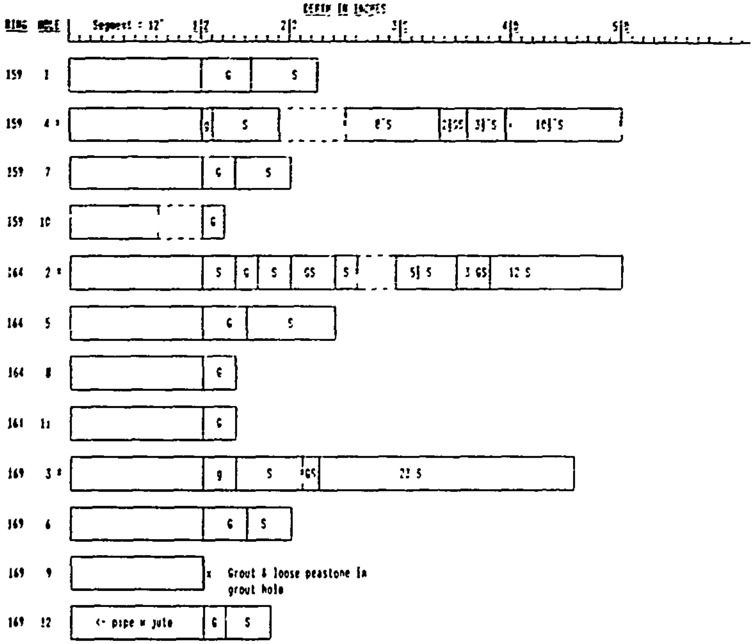
G : Grout w peastone
g : Grout w no peastone
S : Shale
GS : Grout / shale mix
W : Wood
C : Caulk
F : Styrofoam
D : Debris w grout
x : Thin layer of grout

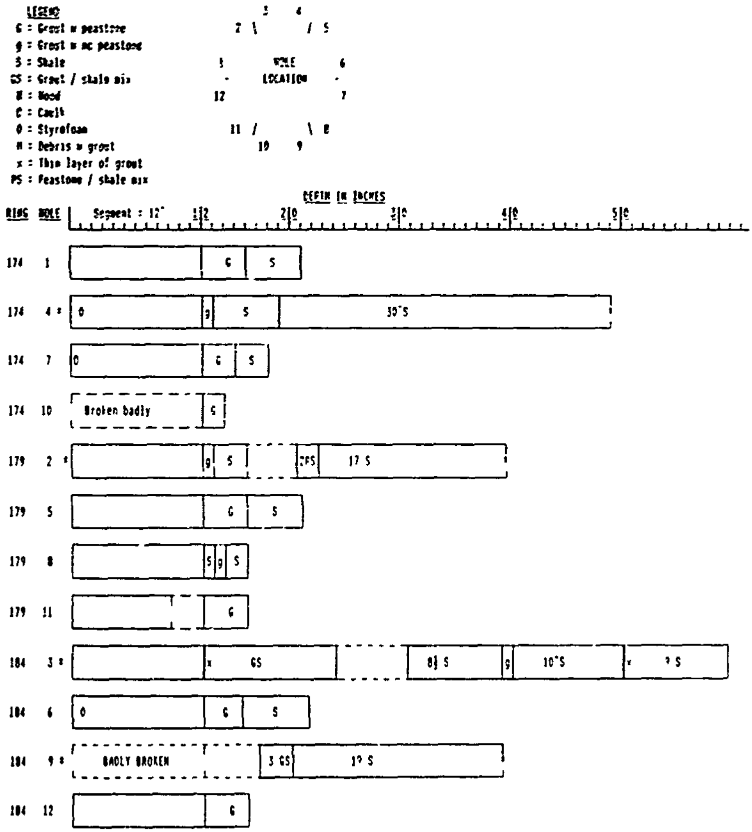


LEGEND

G : Grout w peastone
g : Grout w no peastone
S : Shale
GS : Grout / shale mix
W : Wood
C : Caulk
? : Styrofoam
: Debris w grout
x : Thin layer of grout



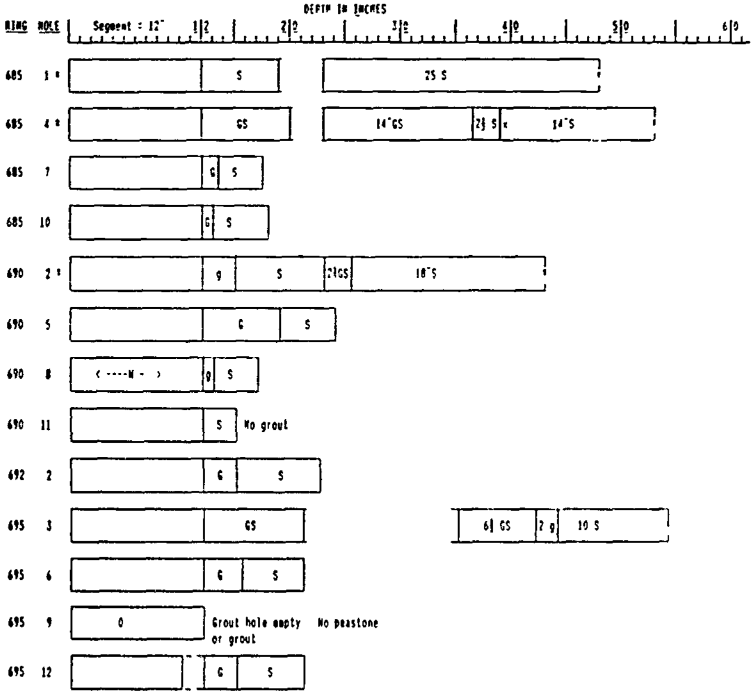




LEGEND
G : Grout w peastone
g : Grout w no peastone
S : Shale
GS : Grout / shale mix
W : Wood
C : Caulk
0 : Styrofoam
: Debris w grout
x : Thin layer of grout
PS : Peastone / shale mix
HOLE LOCATION
1 2 3 4 5 6 7 8 9 10 11 12
DEPTH IN INCHES
RING HOLE Segment : 12"
12
20
30
40
50
174 1 G S
174 4 * 0 g S 30"S
174 7 0 G S
174 10 Broken badly S
179 2 * g S PS 17 S
179 5 G S
179 8 S g S
179 11 G
184 3 * x GS 8½ S g 10"S x S
184 6 0 G S
184 9 * BADLY BROKEN 3 GS 19 S
184 12 G

LEGEND
G : Grout w peastone
g : Grout w/o peastone
GS : Grout / shale mix
S : Shale
|x : Thin layer grout
W : Wood
0 : Caulk
0 : Styrofoam
N : Debris w grout
* : Actual measured depth of core hole

3 4 5 6 7 8 9 10 11 12 1 2
HOLE LOCATION

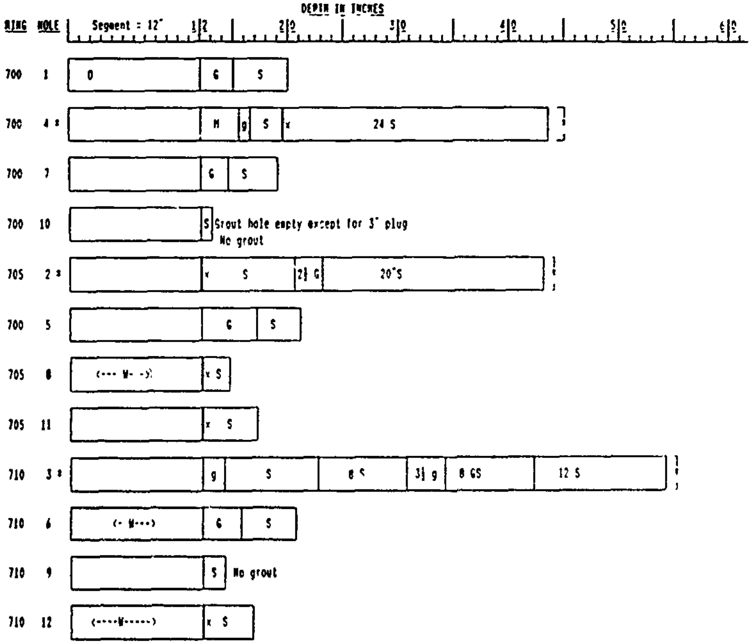


LEGEND

- G = Grout w peastone
- g = Grout w/o peastone
- GS = Grout / shale mix
- S = Shale
- |x = Thin layer grout
- W = Wood
- 0 = Caulk
- Θ = Styrofoam
- M = Debris w grout
- * = Actual measured depth of core hole

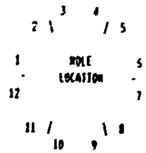
HOLE LOCATION

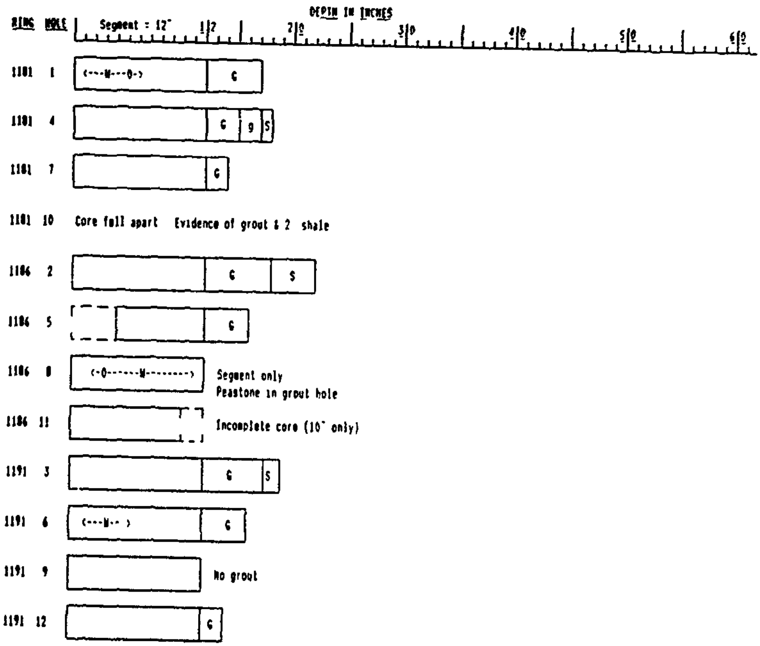
```
        3     4
   2 \           / 5

 1                   6
 -     HOLE LOCATION  -
 12                  7

   11 /          \ 8
        10    9
```



LEGEND

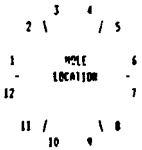
- G = Grout w peastone
- g = Grout w/o peastone
- GS = Grout / shale mix
- S = Shale
- |x = Thin layer grout
- W = Wood
- 0 = Caulk
- 0 = Styrofoam
- # = Debris w grout
- * = Actual measured depth of core hole





LEGEND

G = Grout w peastone
g = Grout w/o peastone
GS = Grout / shale mix
S = Shale
|x = Thin layer grout
W = Wood
D = Caulk
O = Styrofoam
M = Debris w grout
* = Actual measured depth of core hole



DEPTH IN INCHES

Segment = 12"; scale: 12, 20, 30, 40, 50, 60

RING	HOLE	Core
1196	1	[<----W---->] [G]
1196	4	[ ] [G] [g] [S]
1196	7	[ ] [G]
1196	10	Core fell apart Evidence of grout w/o peastone
1201	2	[ ] [G]
1201	5	[ ] [G]
1201	8	[ ] Core included segment only Grout in grout hole
1201	11	[ ] |x Segment only Traces of grout
1206	3	[ ] [G] [g]
1206	6	[<--- - W - - ->] [G]
1206	9	[ ] Segment only No grout
1206	12	[ ] [G]

APPENDIX D

Drilled Shaft Logs

DRILLING LOG	DIVISION Southwestern-COE	INSTALLATION San Antonio Tunnels Resident Office	SHEET 1 OF 3 SHEETS

1. PROJECT: San Pedro Creek Tunnel, San Antonio Texas
2. LOCATION (Coordinates or Station): Station 143+00 (near Outlet Shaft)
3. DRILLING AGENCY: Beck Foundations
4. HOLE NO. (As shown on drawing title and file number): Hydraulic Instrumentation Shaft
5. NAME OF DRILLER: Al Mann
6. DIRECTION OF HOLE: [X] VERTICAL [ ] INCLINED ______ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN: 27.0 ft.
8. DEPTH DRILLED INTO ROCK: 92.2 ft.
9. TOTAL DEPTH OF HOLE: 119.2 ft.
10. SIZE AND TYPE OF BIT: See Remark 2
11. DATUM FOR ELEVATION SHOWN (TBM or MSL): MSL
12. MANUFACTURER'S DESIGNATION OF DRILL: Northwest 5045 (45 ton)
13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: DISTURBED None; UNDISTURBED None
14. TOTAL NUMBER CORE BOXES: N/A
15. ELEVATION GROUND WATER: 618.2 El.
16. DATE HOLE: STARTED 25 April 88; COMPLETED 25 April 88
17. ELEVATION TOP OF HOLE: 638.2 El.
18. TOTAL CORE RECOVERY FOR BORING: N/A
19. SIGNATURE OF INSPECTOR: Robert A. Burns

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	Casing	Geol. Unit	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) e
638.2	0.0'		0.0'-2.0' Clay Fill: dark brown to black, medium plasticity, with scattered sand and angular gravel.	25.5" dia. casing; 12" dia. casing	Recent	1. Water Level: free water encountered from 20.0 ft. to 27.0 ft. depth.
			2.0'-8.0' Clay: brown to grayish brown, medium plasticity, silty in places and stiff.			2 Drilling Method: A 24" dia. full flight auger bored 27 0 ft. reamed shaft to 26" dia. set 25 5" dia. casing through overburden, seated casing in weathered clay shale.
			8 0'-12.0' Clay: tan to buff, medium to high plasticity, stiff and damp.		Qal	Continued boring with 24" dia flight auger to a depth of 119.2 ft., cased 119 2 ft bore hole with schedule 40, 12" dia. well casing
			12.0'-20.0' Gravelly Clay: tan to grayish brown, medium to high plasticity, with numerous calcareous concreations, sand seams and damp			Filled shaft with 2 feet of clay fill, grout annular spaces around 12" dia. casing to ground level and capped casing. Withdrew 25 5" casing and backfilled with grout
			20.0'-27.0' Clayey Gravel: grayish brown, well graded rounded gravel with clay and rounded calcareous concreations, saturated.		Qal	
618.2	20.0'		27.0'-39.6' Weathered Clay Shale: tan and gray, medium to high plasticity, soft, blocky in places, iron staining along frequent fractures and joints, calcareous. Taylor Shale (Kt) of Cretaceous Period.		Qal	3 Geologic Units: Qal-unconsolidated alluvial deposits of the Quaternary Period. Kt-Taylor Shale, clay shale of the Cretaceous Period.
611.2	27.0'					
					Kt	
598.2	40.0'					

ENG FORM 1836 PREVIOUS EDITIONS ARE OBSOLETE

PROJECT San Antonio Tunnels | HOLE NO. SP-1

DRILLING LOG	DIVISION Southwestern-COE	INSTALLATION San Antonio Tunnels Resident Office	SHEET 2 OF 3 SHEETS
1. PROJECT San Pedro Creek Tunnel, San Antonio Texas		10. SIZE AND TYPE OF BIT See Remark 2	
2. LOCATION (Coordinates or Station) Station 143+00 (near Outlet Shaft)		11. DATUM FOR ELEVATION SHOWN (TBM or MSL) MSL	
3. DRILLING AGENCY Beck Foundations		12. MANUFACTURER'S DESIGNATION OF DRILL Northwest 5045 (45 ton)	
4. HOLE NO. (As shown on drawing title and file number) Hydraulic Instrumentation Shaft		13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED None; UNDISTURBED None	
5. NAME OF DRILLER Al Mann		14. TOTAL NUMBER CORE BOXES N/A	
6. DIRECTION OF HOLE [X] VERTICAL [ ] INCLINED ____ DEG. FROM VERT.		15. ELEVATION GROUND WATER 618.2 El.	
		16. DATE HOLE: STARTED 25 April 88; COMPLETED 25 April 88	
7. THICKNESS OF OVERBURDEN 27.0 ft.		17. ELEVATION TOP OF HOLE 638.2 El.	
8. DEPTH DRILLED INTO ROCK 92.2 ft.		18. TOTAL CORE RECOVERY FOR BORING N/A	
9. TOTAL DEPTH OF HOLE 119.2 ft.		19. SIGNATURE OF INSPECTOR Robert A. Burns	

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	Casing	Geol. Unit	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) e
598.2	40.0		39.6'-119.2' Clay Shale: gray to light gray, soft to occasionaly moderately hard in the more calcareous zones, calcareous throughout but becomes more so with depth, massive, moderate petroleum odor, fossils observed in places, occasional pyrite. Taylor Shale (Kt) of Cretaceous Period	12" dia. casing	Kt	
578.2	60.0				Kt	
558.2	80.0					

DRILLING LOG	DIVISION Southwestern-COE	INSTALLATION San Antonio Tunnels Resident Office	SHEET 3 of 3 SHEETS

1. PROJECT San Pedro Creek Tunnel, San Antonio Texas	10. SIZE AND TYPE OF BIT See Remark 2
2. LOCATION (Coordinates or Station) Station 143+00 (near Outlet Shaft)	11. DATUM FOR ELEVATION SHOWN (TBM or MSL) MSL
3. DRILLING AGENCY Beck Foundations	12. MANUFACTURER'S DESIGNATION OF DRILL Northwest 5045 (45 ton)
4. HOLE NO. (As shown on drawing title and file number) Hydraulic Instrumentation Shaft	13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: DISTURBED None; UNDISTURBED None
5. NAME OF DRILLER Al Mann	14. TOTAL NUMBER CORE BOXES N/A
6. DIRECTION OF HOLE [X] VERTICAL [ ] INCLINED ____ DEG. FROM VERT.	15. ELEVATION GROUND WATER 618.2 El.
	16. DATE HOLE: STARTED 25 April 88; COMPLETED 25 April 88
7. THICKNESS OF OVERBURDEN 27.0 ft.	17. ELEVATION TOP OF HOLE 638.2 El.
8. DEPTH DRILLED INTO ROCK 92.2 ft.	18. TOTAL CORE RECOVERY FOR BORING N/A
9. TOTAL DEPTH OF HOLE 119.2 ft.	19. SIGNATURE OF INSPECTOR Robert A. Burns

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	Casing	Geol. Unit	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
558.2	80.0		Refer to description on Sheet 2.	12" dia casing	Kt	
538.2	100.0				Kt	
521.0	117.0			Clay Fill		
519.0						
	120.0		shaft bottom			

DRILLING LOG	DIVISION Southwesterr-COE	INSTALLATION San Antonio Tunnels Resident Office	SHEET 1 of 4 SHEETS

1 PROJECT: San Pedro Creek Tunnels, San Antonio, Texas

2 LOCATION (Coordinates or Station): Station 158+14.13 (near Durango St.)

3 DRILLING AGENCY: A. H. Beck Foundation

4 HOLE NO (As shown on drawing title and file number): Ventilation shaf

5 NAME OF DRILLER: Al Mann

6 DIRECTION OF HOLE: [X] VERTICAL [ ] INCLINED ______ DEG FROM VERT

7 THICKNESS OF OVERBURDEN: 23.0

8 DEPTH DRILLED INTO ROCK: 98.0

9 TOTAL DEPTH OF HOLE: 121.0

10 SIZE AND TYPE OF BIT: See Remark 2

11 DATUM FOR ELEVATION SHOWN (TBM or MSL): MSL

12 MANUFACTURER'S DESIGNATION OF DRILL: Northwest 5045 (45 ton)

13 TOTAL NO OF OVERBURDEN SAMPLES TAKEN: DISTURBED None; UNDISTURBED None

14 TOTAL NUMBER CORE BOXES: N/A

15 ELEVATION GROUND WATER: 623.3 El.

16 DATE HOLE: STARTED 11 May 88; COMPLETED 13 May 88

17 ELEVATION TOP OF HOLE: 639.3 El.

18 TOTAL CORE RECOVERY FOR BORING: N/A

19 SIGNATURE OF INSPECTOR: Roy Crutchfield

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	Casing	Geol. Unit	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) e
639.3	0.0		0.0'-1.5' Sand Fill tan, fine to coarse grained, contains some fine to med. gravel, occ. glass and metal debris, loose.	78" dia casing; 48" dia casing		1 Water Level free water encountered at 16.0 to 23.0 ft depth
	1.5		1.5'-12.0' Gravelly Clay buff to dark brown, medium to high plasticity, contains scattered small to medium rounded limestone and chert gravel, soft to stiff		Qal	2 Drilling Method A 78" dia full flight auger bored 30 ft, set a 78" dia casing through overburden, seated casing within weathered clay shale to seal ground water. Continued shaft sinking with a 48" dia full flight auger to 121ft depth, widened shaft to 72" dia, backfilled with clay to 117.7 ft depth,
627.3	12.0		12.0'-23.0' Clayey Gravel tan and gray, subrounded to rounded limestone and chert gravel, moderately clayey, saturated below 16.0'.		Qal	Set 48" dia permanent casing, backfilled annulus with concrete
623.3	16.0					3 Geologic Units Qal -Unconsolidated alluvial deposits of the Quaternary Period Kt -Taylor Shale, clay shale of the Cretaceous Period
616.3	23.0		23.0'-39.8' Weathered Clay Shale: yellowish tan and gray, medium to high plasticity, soft, blocky with frequent joints and fractures, some iron staining, damp, calcareous. Taylor Shale of Cretaceous Period.			
610.8	28.5				Kt	
599.3	40.0					

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE | PROJECT San Antonio Tunnels | HOLE NO. SP-2

DRILLING LOG	DIVISION Southwestern-COE	INSTALLATION San Antonio Tunnels Resident Office	SHEET OF SHEETS

1. PROJECT San Pedro Creek Tunnels San Antonio, Texas
2. LOCATION Station 358+14.13 (near Durango St.)
3. DRILLING AGENCY A. H. Beck Foundation
4. HOLE NO. Ventilation shaft
5. NAME OF DRILLER Al Mann
6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED ____ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN 23.0
8. DEPTH DRILLED INTO ROCK 98.0
9. TOTAL DEPTH OF HOLE 121.0
10. SIZE AND TYPE OF BIT See Remark 2
11. DATUM FOR ELEVATION SHOWN (TBM or MSL) MSL
12. MANUFACTURER'S DESIGNATION OF DRILL Northwest 5045 (45 ton)
13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN DISTURBED None UNDISTURBED None
14. TOTAL NUMBER CORE BOXES N/A
15. ELEVATION GROUND WATER 623.3
16. DATE HOLE STARTED 11 May 88 COMPLETED 13 May 88
17. ELEVATION TOP OF HOLE 639.3 ft
18. TOTAL CORE RECOVERY FOR BORING N/A
19. SIGNATURE OF INSPECTOR Roy Crutchfield

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	Casing	Geol. Unit	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) e
599.3	40.0		39.8'-121.0' Clay Shale: gray, soft to moderately soft, massive, calcareous to very calcareous occasional fossils, pyrite scattered throughout, emits a slight petroleum odor. Taylor Shale (Kt) of Cretaceous Period.	48" dia casing	Kt	
579.3	60.0					
559.3	80.0					

ENG FORM 1836 PREVIOUS EDITIONS ARE OBSOLETE PROJECT San Antonio Tunnels HOLE NO. VS-2

DRILLING LOG	DIVISION Southwestern-COE	INSTALLATION San Antonio Tunnels Resident Off:	SHEET 2 OF 2 SHEETS

1. PROJECT San Pedro Creek Tunnels, San Antonio, Texas
2. LOCATION (Coordinates or Station) Station 158+14.13 (near Durango St.)
3. DRILLING AGENCY A. H. Beck Foundation
4. HOLE NO. (As shown on drawing title and file number) Ventilation shaf
5. NAME OF DRILLER R. Mann
6. DIRECTION OF HOLE: [X] VERTICAL [ ] INCLINED ______ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN 23.0
8. DEPTH DRILLED INTO ROCK 98.0
9. TOTAL DEPTH OF HOLE 121.0
10. SIZE AND TYPE OF BIT See remark 2
11. DATUM FOR ELEVATION SHOWN (TBM or MSL) MSL
12. MANUFACTURER'S DESIGNATION OF DRILL Northwest 5045 (45 ton)
13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED None; UNDISTURBED None
14. TOTAL NUMBER CORE BOXES N/A
15. ELEVATION GROUND WATER 623.3 El.
16. DATE HOLE: STARTED 11 May 88; COMPLETED 13 May 88
17. ELEVATION TOP OF HOLE 639.3 El
18. TOTAL CORE RECOVERY FOR BORING N/A
19. SIGNATURE OF INSPECTOR Roy Crutchfield

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	Casing	Geol. Unit	REMARKS e
559.3	80.0		Refer to description on sheet 2.			
539.3	100.0			10" dia. casing	Kt	
521.6	117.7			Cln. Fill		
519.3	120.0					

ENG FORM 1836 PREVIOUS EDITIONS ARE OBSOLETE | PROJECT San Antonio Tunnels | HOLE NO.

DRILLING LOG	DIVISION Southwestern-COE	INSTALLATION San Antonio Tunnels Resident Office	SHEET OF SHEETS

1. PROJECT San Pedro Creek Tunnels, San Antonio, Texas	10. SIZE AND TYPE OF BIT See Remark 2
2. LOCATION (Coordinates or Station) Station 158+14.13 (near Durango St.)	11. DATUM FOR ELEVATION SHOWN (TBM or MSL) MSL
3. DRILLING AGENCY R. B. Beck Foundation	12. MANUFACTURER'S DESIGNATION OF DRILL Northwest 5045 (45 ton)
4. HOLE NO. (As shown on drawing title and file number) ventilation shaf	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN — DISTURBED: None; UNDISTURBED: None
5. NAME OF DRILLER Al Jaime	14. TOTAL NUMBER CORE BOXES N/A
6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED ___ DEG. FROM VERT.	15. ELEVATION GROUND WATER 623.3 El.
	16. DATE HOLE — STARTED 11 May 88; COMPLETED 13 May 88
7. THICKNESS OF OVERBURDEN 23.0	17. ELEVATION TOP OF HOLE 639.3 El
8. DEPTH DRILLED INTO ROCK 98.0	18. TOTAL CORE RECOVERY FOR BORING N/A
9. TOTAL DEPTH OF HOLE 121.0	19. SIGNATURE OF INSPECTOR Roy Crutchfield

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	Casing	Geol. Unit	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) e
	120.0'		120.0': observed occ. fossils	Fill	Kt	
	121.0'		shaft bottom			

ENG FORM 1836 PREVIOUS EDITIONS ARE OBSOLETE — PROJECT San Antonio Tunnels — HOLE NO. SP-2

DRILLING LOG	DIVISION Southwestern-COE	INSTALLATION San Antonio Tunnels Resident Office	SHEET 1 OF 4 SHEETS
1. PROJECT San Pedro Creek Tunnel		10. SIZE AND TYPE OF BIT See Remark 2	
2. LOCATION (Coordinates or Station) Station 181+77.08 (Camaron St.)		11. DATUM FOR ELEVATION SHOWN (TBM or MSL) MSL	
3. DRILLING AGENCY Beck Foundations		12. MANUFACTURER'S DESIGNATION OF DRILL Northwest 5045 (45 Ton)	
4. HOLE NO. (As shown on drawing title and file number)	Maintenance Shaft	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN	DISTURBED None / UNDISTURBED None
5. NAME OF DRILLER Al Mann		14. TOTAL NUMBER CORE BOXES None	
6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED ____ DEG. FROM VERT.		15. ELEVATION GROUND WATER	
7. THICKNESS OF OVERBURDEN 16 ft.		16. DATE HOLE	STARTED 9 May 88 / COMPLETED 11 August 88
8. DEPTH DRILLED INTO ROCK 106 ft.		17. ELEVATION TOP OF HOLE 642.5	
9. TOTAL DEPTH OF HOLE 122.0 ft.		18. TOTAL CORE RECOVERY FOR BORING N/A	
		19. SIGNATURE OF INSPECTOR R.A. Burns & Roy Crutchfield	

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	Casing	Geol. Unit	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) e
642.5	0.0		0.0' to 0.2' Asphalt parking lot surface. 0.2' to 7.3' Clay Fill: brown, medium plasticity, mod. stiff, sandy to gravelly with angular to rounded grains, contains brick and metal debris, dry. 7.3' to 16.0' Clay: tan to buff with some gray mottling, medium to high plasticity, fine to coarse gravel in places, also 1" to 2" dia. limestone concretions in the upper foot, numerous scattered lime pockets, damp below 12' depth.	36" dia concrete soldier piers		1. Water Level: No free water observed while drilling soldier piers. After piers were installed a trace of wetness developed between two of the piers on the SW side of the shaft. 2. Excavation Procedure Initially a ring of 27 drilled, concrete soldier piers were constructed to just within the top of unweathered shale, to depths from 36' to 42' The piers were 36" dia. and formed an inside shaft dia. of 21'6". The interior of the ring was excavated with a backhoe and crane w/skip box. This method of excavation continued below the pier bottoms to the 50' depth, with 6" of shotcrete support below the piers. The remainder of the shaft was drilled and reamed to a dia of 22'4" and to a total depth of 122.0 ft. Sodier piers were constructed by Cato Electric and Drilling.
626.5	16.0		16.0' to 33.8' Weathered Clay Shale tan and gray, high plasticity, compact, soft, blocky, occaional fossils. Taylor Shale (Kt) of the Cretaceous Period. 33.8' to 42.5' Clay Shale Unweathered except along fractures and joints, dark gray with reddish tan 1" to 2" oxidized seams along fractures and joints, massive, soft, cont ains nearly horizontal joints at 40' and 42' depths with several high angle joints and irregular fractures.		Kt Kt	
602.5	40.0					

ENG FORM 1836 PREVIOUS EDITIONS ARE OBSOLETE | PROJECT San Antonio Tunnels | HOLE NO. SPL-3

DRILLING LOG	DIVISION Southwestern-COE	INSTALLATION San Antonio Tunnels Resident Office	SHEET 2 OF 4 SHEETS

1. PROJECT San Pedro Creek Tunnel	10. SIZE AND TYPE OF BIT see Remark 2
2. LOCATION (Coordinates or Station) Station 181+77.08 (Camaron St.)	11. DATUM FOR ELEVATION SHOWN (TBM or MSL) MSL
3. DRILLING AGENCY Beck Foundations	12. MANUFACTURER'S DESIGNATION OF DRILL Northwest 5045 (45 Ton)
4. HOLE NO. (As shown on drawing title and file number) Maintenance Shaft	13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: DISTURBED None; UNDISTURBED None
5. NAME OF DRILLER Al Mann	14. TOTAL NUMBER CORE BOXES None
6. DIRECTION OF HOLE [X] VERTICAL [ ] INCLINED ___ DEG. FROM VERT.	15. ELEVATION GROUND WATER
	16. DATE HOLE: STARTED 9 May 88; COMPLETED 11 August 88
7. THICKNESS OF OVERBURDEN 16 ft.	17. ELEVATION TOP OF HOLE 642.5
8. DEPTH DRILLED INTO ROCK 106 ft..	18. TOTAL CORE RECOVERY FOR BORING N/A
9. TOTAL DEPTH OF HOLE 122.0 ft.	19. SIGNATURE OF INSPECTOR R.A. Burns & Roy Crutchfield

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	Casing	Geol. Unit	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) e
602.5	40.0		2.5 to 122.0: Clay Shale: light gray to dark gray, soft to moderately hard in limy zones, massive, breaks predominantly with conchoidal fracture, calcareous to very calcareous or limy, occasional fossils, scattered pyrite crystals, petroleum odor. Taylor Shale (Kt) of Cretaceous Period.		Kt	3. Geologic Units: Qal-Unconsolidated alluvial deposits of Quaternary Period. Kt-Taylor Shale, clay shale of Cretaceous Period.
582.5	60.0		60.0 to 70.0: occasional 4" to 6" thick, mod. hard, limy layers.	6" of shotcrete support		
			70.0 to 76.0: lt. gray, massive dense, well indurated, limy, occasional fossils, and strong petroleum odor.		Kt	
562.5	80.0					

DRILLING LOG	DIVISION Southwestern-COE	INSTALLATION San Antonio Tunnels Resident Office	SHEET 3 OF 4 SHEETS

1. PROJECT San Pedro Creek Tunnel	10. SIZE AND TYPE OF BIT See Remark 2
2. LOCATION (Coordinates or Station) Station 181+77.08 (Camaron St.)	11. DATUM FOR ELEVATION SHOWN (TBM or MSL) MSL
3. DRILLING AGENCY Beck Foundations	12. MANUFACTURER'S DESIGNATION OF DRILL Northwest 5045 (45 Ton)
4. HOLE NO. (As shown on drawing title and file number) Maintenance Shaft	13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN — DISTURBED: None; UNDISTURBED: None
5. NAME OF DRILLER Al Mann	14. TOTAL NUMBER CORE BOXES None
6. DIRECTION OF HOLE [X] VERTICAL [ ] INCLINED ___ DEG. FROM VERT.	15. ELEVATION GROUND WATER
7. THICKNESS OF OVERBURDEN 16 ft.	16. DATE HOLE — STARTED: 9 May 88; COMPLETED: 11 August 88
8. DEPTH DRILLED INTO ROCK 106 ft.	17. ELEVATION TOP OF HOLE 642.5
9. TOTAL DEPTH OF HOLE 122.0 ft.	18. TOTAL CORE RECOVERY FOR BORING N/A
	19. SIGNATURE OF INSPECTOR R.A. Burns & Roy Crutchfield

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	Casing	Geol. Unit	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) e
562.5	80.0'		Refer to description on sheet 2		Kt	
552.5	90.0'		90.0'-95.0' Light gray, mod. hard, limy clay shale	6" of shotcrete support	Kt	
522.5	120.0'					

DRILLING LOG	DIVISION Southwestern-COE	INSTALLATION San Antonio Tunnels Resident Office	SHEET 1 OF 1 SHEETS

1. PROJECT: San Pedro Creek Tunnel
2. LOCATION (Coordinates or Station): Station 181+77.08 (Camaron St.)
3. DRILLING AGENCY: Beck Foundations
4. HOLE NO (As shown on drawing title and file number): Maintenance Shaft
5. NAME OF DRILLER: Al Mann
6. DIRECTION OF HOLE: [X] VERTICAL [ ] INCLINED ______ DEG FROM VERT
7. THICKNESS OF OVERBURDEN: 16 ft.
8. DEPTH DRILLED INTO ROCK: 106 ft.
9. TOTAL DEPTH OF HOLE: 122.0 ft.
10. SIZE AND TYPE OF BIT: See Remark 2
11. DATUM FOR ELEVATION SHOWN (TBM or MSL): MSL
12. MANUFACTURER'S DESIGNATION OF DRILL: Northwest 5045 (45 Ton)
13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: DISTURBED None; UNDISTURBED None
14. TOTAL NUMBER CORE BOXES: None
15. ELEVATION GROUND WATER:
16. DATE HOLE: STARTED 9 May 88; COMPLETED 11 August 88
17. ELEVATION TOP OF HOLE: 642.5
18. TOTAL CORE RECOVERY FOR BORING: N/A
19. SIGNATURE OF INSPECTOR: R.A. Burns & Roy Crutchfield

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	Casing	Geol. Unit	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) e
520.5	122.0		shaft bottom	shot-crete	Kt	

DRILLING LOG	DIVISION Southwestern-COE	INSTALLATION San Antonio Tunnels Resident Office	SHEET 1 OF 3 SHEETS

1. PROJECT San Pedro Creek Tunnel, San Antonio, Texas	10. SIZE AND TYPE OF BIT See Remark 3
2. LOCATION (Coordinates or Station) Camaron & Salinas St., Sta.185+73.90	11. DATUM FOR ELEVATION SHOWN (TBM or MSL) MSL
3. DRILLING AGENCY A. H. Beck Foundation	12. MANUFACTURER'S DESIGNATION OF DRILL Northwest 5045 (45 ton)
4. HOLE NO. (As shown on drawing title and file number) ventilation shaft	13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: DISTURBED None; UNDISTURBED None
5. NAME OF DRILLER Al Mann	14. TOTAL NUMBER CORE BOXES N/A
6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED ___ DEG. FROM VERT.	15. ELEVATION GROUND WATER 630.0 El.
	16. DATE HOLE: STARTED 2 May 88; COMPLETED 4 May 88
7. THICKNESS OF OVERBURDEN 13.58 ft.	17. ELEVATION TOP OF HOLE 643.0 El.
8. DEPTH DRILLED INTO ROCK 103.42 ft.	18. TOTAL CORE RECOVERY FOR BORING N/A
9. TOTAL DEPTH OF HOLE 117.00 ft.	19. SIGNATURE OF INSPECTOR Roy Crutchfield

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	Casing	Geol. Unit	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) e
643.0	0.0		0.0'-2.5' Gravelly Clay Fill. gray, low to medium plasticity, gravelly with chert nodules, some brick, ceramics and other debris scattered throughout			1. Water Level: Some free water was observed flowing from red oxidized, jointed clay at 13.0' to 13.58' depth
			2.5'-5.0' Clay: dark gray, low plasticity, soft, thin soft caliche layer near basal contact.		Qal	2. Clay Drain Tile: Damaged 6" dia. drain tile at 2 ft. depth
			5.0'-13.58' Clay tan and gray mottled, high plasticity, soft, blocky moist, with red iron stains along healed joints, contains small scattered limy pockets.	96" dia. casing		
629.42	13.58		13.58'-31.0' Weathered Clay Shale Yellowish tan and gray mottled, soft, blocky, highly jointed and fractured with red iron staining along upper contact. Taylor Shale (Kt) of Cretaceous Period.			3. Drilling Method: Augered a 78" dia. boring to 17 ft., reamed to 96" dia. and set 96" dia. casing. Continued with a 78" dia. full flight auger to the 117 ft. depth. Backfilled to 114ft., set 48" casing to 114 ft., filled the remaining annular space with concrete, pulled 96" dia. casing, sealed off shaft opening with metal plate (refer to remarks 5&6 to explain thicker concrete shaft wall.)
626.0	17.0				Kt	
623.0	20.0			48" dia. casing		
612.0	31.0		31.0'-117.0' Clay Shale: lightgray to dark gray, soft to moderately hard, massive, has mild to strong petroleum odor, contains occasional fossils and pyrite crystals, calcareous to very calcareous, becomes moderately hard in limy zones. Taylor Shale (Kt) of Cretaceous Period.			
603.0	40.0				Kt	

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT)

PROJECT San Antonio Tunnels | HOLE NO. SP-4

DRILLING LOG	DIVISION Southwestern-COE	INSTALLATION San Antonio Tunnels Resident Office	SHEET 2 of 3 SHEETS

1. PROJECT San Pedro Creek Tunnel San Antonio Texas	10. SIZE AND TYPE OF BIT See Remark 3
2. LOCATION (Coordinates or Station) Camaron & Salinas St., Sta.185+73.90	11. DATUM FOR ELEVATION SHOWN (TBM or MSL) MSL
3. DRILLING AGENCY A. H. Beck Foundation	12. MANUFACTURER'S DESIGNATION OF DRILL Northwest 5045 (45 ton)
4. HOLE NO. (As shown on drawing title and file number) ventilation shaft	13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: DISTURBED None; UNDISTURBED None
5. NAME OF DRILLER Al Mann	14. TOTAL NUMBER CORE BOXES N/A
6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED ____ DEG. FROM VERT.	15. ELEVATION GROUND WATER 630.0 El.
	16. DATE HOLE: STARTED 2 May 88; COMPLETED 4 May 88
7. THICKNESS OF OVERBURDEN 13.58 ft.	17. ELEVATION TOP OF HOLE 643.0 El.
8. DEPTH DRILLED INTO ROCK 103.42 ft.	18. TOTAL CORE RECOVERY FOR BORING N/A
9. TOTAL DEPTH OF HOLE 117.00 ft.	19. SIGNATURE OF INSPECTOR Roy Crutchfield

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	Casing	Geol. Unit	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
603.0	40.0					4. Geologic Units Qal - Unconsolidated alluvial deposits of the Quaternary Period. Kt - Taylor Shale, clay shale of Cretaceous Period.
601.0	42.0		42.0'-45.0': Light gray, massive, moderately soft, very calcareous or limy.		Kt	
583.0	60.0			48" dia. casing	Kt	
578.0	65.0		65.0'-70.0': Light gray, massive, moderately soft to moderately hard, highly calcareous, with occasional fossils, pyrite crystals, and mild petroleum odor when broken.			
563.0	80.0					

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE

PROJECT San Antonio Tunnels | HOLE NO. SP-4

DRILLING LOG	DIVISION Southwestern-COE	INSTALLATION San Antonio Tunnels Resident Office	SHEET 3 OF 3 SHEETS

1. PROJECT San Pedro Creek Tunnel, San Antonio Texas	10. SIZE AND TYPE OF BIT See Remark 3
2. LOCATION (Coordinates or Station) Camaron & Salinas St., Sta. 185+73.90	11. DATUM FOR ELEVATION SHOWN (TBM or MSL) MSL
3. DRILLING AGENCY A. H. Beck Foundation	12. MANUFACTURER'S DESIGNATION OF DRILL Northwest 5045 (45 ton)
4. HOLE NO. (As shown on drawing title and file number) ventilation shaft	13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: DISTURBED None; UNDISTURBED None
5. NAME OF DRILLER Al Mann	14. TOTAL NUMBER CORE BOXES N/A
6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED ___ DEG. FROM VERT.	15. ELEVATION GROUND WATER 630.0 El.
	16. DATE HOLE STARTED 2 May 88; COMPLETED 4 May 88
7. THICKNESS OF OVERBURDEN 13.58 ft.	17. ELEVATION TOP OF HOLE 643.0 El.
8. DEPTH DRILLED INTO ROCK 103.42 ft.	18. TOTAL CORE RECOVERY FOR BORING N/A
9. TOTAL DEPTH OF HOLE 117.00 ft.	19. SIGNATURE OF INSPECTOR Roy Crutchfield

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	Casing	Geol. Unit	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) e
563.0	80.0'					
558.0	85.0'		85.0'-117.00': Light gray, massive, mod. soft to mod. hard, very calcareous, with many fossils, large pyrite crystals and mild petroleum odor when broken		Kt	5. 85.0'-117.0' Clay shale became harder, driller exchanged flat auger teeth for pointed "Tiger Teeth", and pumped water from creek into shaft to assist sinking operation
55	90.0'			48" dia casing		6. 90.0'-117.0' Shaft began to plunge towards the west (San Pedro Creek 24" dia and 36" dia pilot holes were bored to help re-align shaft and guide 72" dia auger The hole was then reamed out to the 78" dia Alignment rechecked and found to be within contract tolerances.
543.0	100.0'					
					Kt	
529.0	114.0'			Clay Fill		
526.0	117.0'		Shaft bottom			

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE — PROJECT San Antonio Tunnels — HOLE NO. SP-4

DRILLING LOG	DIVISION Southwestern-COE	INSTALLATION San Antonio Tunnels Resident Office	SHEET 1 OF 3 SHEETS

1. PROJECT: San Pedro Creek Tunnel, San Antonio, Texas
2. LOCATION: Station 199+81.31 (near Inlet Shaft)
3. DRILLING AGENCY: A. H. Beck Foundation
4. HOLE NO.: Hydraulic Instrumentation Shaft
5. NAME OF DRILLER: Al Mann
6. DIRECTION OF HOLE: ☒ VERTICAL ☐ INCLINED ____ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN: 11.8 ft.
8. DEPTH DRILLED INTO ROCK: 95.0 ft.
9. TOTAL DEPTH OF HOLE: 107.0 ft.
10. SIZE AND TYPE OF BIT: See Remark 2
11. DATUM FOR ELEVATION SHOWN (TBM or MSL): MSL
12. MANUFACTURER'S DESIGNATION OF DRILL: Northwest 5045 (45 ton)
13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: None / None
14. TOTAL NUMBER CORE BOXES: N/A
15. ELEVATION GROUND WATER: 630.8 El.
16. DATE HOLE: STARTED 28 April 88, COMPLETED 28 April 88
17. ELEVATION TOP OF HOLE: 635.8 El.
18. TOTAL CORE RECOVERY FOR BORING: N/A
19. SIGNATURE OF INSPECTOR: Robert A. Burns

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	Casing	Geol Unit	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) e
635.8	0.0'		0.0'-0.83' San Pedro Creek Concrete Liner: 10" thick, reinforced with #3 bars. 0.83'-11.8' Weathered Clay Shale: tan and gray mottled, high plasticity, soft, somewhat blocky, moist. Taylor Shale (Kt) of Cretaceous Period.	54" dia	Kt	1. Water Level trace of free water observed at 5 ft. depth 2. Drilling Method: Bored through San Pedro Creek liner with 54" dia. core barrel, inserted a 54" dia. casing 3 ft below top of concrete liner to divert Creek water around shaft.
630.8	5.0					
624.0	11.8		11.8'-107.0' Clay Shale. gray, soft, massive, with lt. gray moderately soft, limy zones increasing with depth, contains fossils and pyrite crystals, emits a strong petroleum odor. Taylor Shale (Kt) of Cretaceous Period.	36" dia. casing	Kt	Replaced 54" dia. core barrel with 36" dia full flight auger. Bored 20 ft. and set 36" dia casing within unweathered clay shale. Continued shaft sinking using a 24" dia full flight auger to 107.0 ft depth, cased full length of shaft with 12" dia. casing, and seated it on backfilled clay from 105.0' to 107.0'.
615.3	20.0			12" dia casing	Kt	Backfilled annular space around 12" dia. casing with grout. Removed 36" dia casing. Set a 24" dia. CMP in grout to stand 2 ft. above the creek. When grout had hardened, removed 54" dia. casing and capped 12" dia. casing.
595.8	40.0'					

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT)

PROJECT: San Antonio Tunnels — HOLE NO.: SP-5

DRILLING LOG	DIVISION Southwestern-COE	INSTALLATION San Antonio Tunnels Resident Office	SHEET 2 OF SHEETS

1. PROJECT: San Pedro Creek Tunnel San Antonio, Texas
2. LOCATION (Coordinates or Station): Station 199+81.31 (near Inlet Shaft)
3. DRILLING AGENCY: A. H. Beck Foundation
4. HOLE NO. (As shown on drawing title and file number): Hydraulic Instrumentation Shaft
5. NAME OF DRILLER: Al Mann
6. DIRECTION OF HOLE: [X] VERTICAL [ ] INCLINED ______ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN: 11.8 ft.
8. DEPTH DRILLED INTO ROCK: 95.0 ft.
9. TOTAL DEPTH OF HOLE: 107.0 ft.
10. SIZE AND TYPE OF BIT: See Remark 2
11. DATUM FOR ELEVATION SHOWN (TBM or MSL): MSL
12. MANUFACTURER'S DESIGNATION OF DRILL: Northwest 3045 (45 ton)
13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED None; UNDISTURBED None
14. TOTAL NUMBER CORE BOXES: N/A
15. ELEVATION GROUND WATER: 630.8 El.
16. DATE HOLE: STARTED 28 April 88; COMPLETED 28 April 88
17. ELEVATION TOP OF HOLE: 635.8 El.
18. TOTAL CORE RECOVERY FOR BORING: N/A
19. SIGNATURE OF INSPECTOR: Robert A. Burns

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	Casing	Geol Unit	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
595.8	40.0'		For general rock classificationsee sheet 1.		Kt	3. Geologic Units: Qal-No unconsolidated alluvial deposits were encountered at this site Kt-Taylor Shale, clay shale of Cretaceous Period.
580.8	55.0'		55.0'-58.0'. Light gray, highly calcareous or limy, moderately soft to moderately hard, massive, with occasional fossils and pyrite crystals.	12" dia. casing		4. Driller replaced flat tipped Auger teeth with "Tiger" teeth to bore through hard limy clay shale.
575.8	60.0'				Kt	
559.8	76.0'		76.0'-107.0': Light gray, highly calcareous, massive, moderately hard, very fossilliferous and abundant large pyrite crystals, mild petroleum odor.			
555.8	80.0'					

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE | San Antonio Tunnels | SP-5

DRILLING LOG	DIVISION Southwestern-COE	INSTALLATION San Antonio Tunnels Resident Ofc.	SHEET 3 OF 3 SHEETS

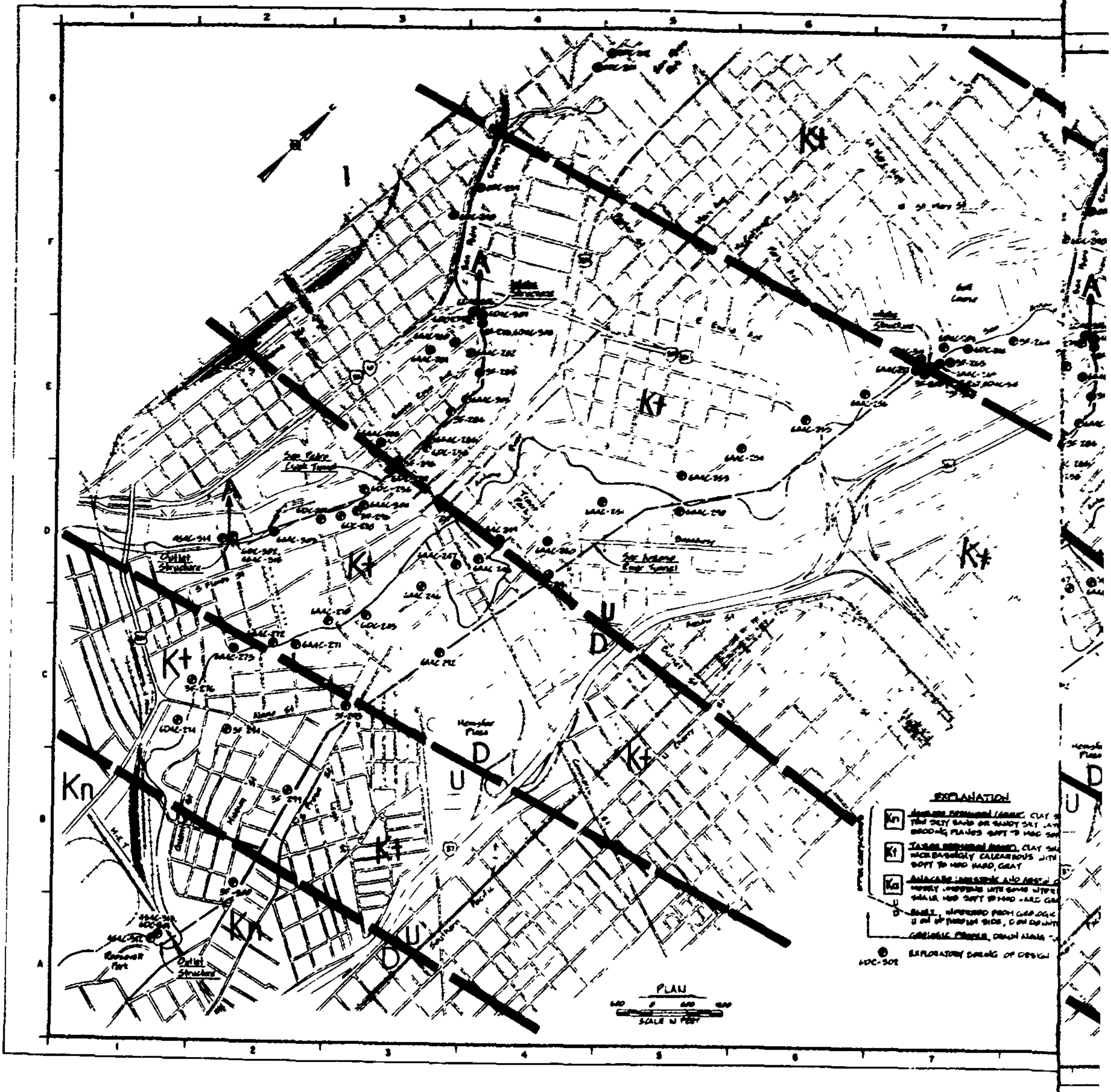
1. PROJECT San Pedro Creek Tunnel, San Antonio, Texas	10. SIZE AND TYPE OF BIT See Remark 2
2. LOCATION (Coordinates or Station) Station 199+31 (near Inlet Shaft)	11. DATUM FOR ELEVATION SHOWN (TBM or MSL) MSL
3. DRILLING AGENCY A.H. Beck Foundation	12. MANUFACTURER'S DESIGNATION OF DRILL Northwest 5054 (45 Ton)
4. HOLE NO. (As shown on drawing title and file number) Hydraulic Instrument Shaft	13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN — DISTURBED: None; UNDISTURBED: None
5. NAME OF DRILLER Al Mann	14. TOTAL NUMBER CORE BOXES N/A
6. DIRECTION OF HOLE [X] VERTICAL [ ] INCLINED ___ DEG. FROM VERT.	15. ELEVATION GROUND WATER 630.8 El.
	16. DATE HOLE — STARTED: 28 April 88; COMPLETED: 28 April 88
7. THICKNESS OF OVERBURDEN 11.8 ft.	17. ELEVATION TOP OF HOLE 635.8 El.
8. DEPTH DRILLED INTO ROCK 95.0 ft.	18. TOTAL CORE RECOVERY FOR BORING N/A
9. TOTAL DEPTH OF HOLE 107.0 ft.	19. SIGNATURE OF INSPECTOR Robert A. Burns

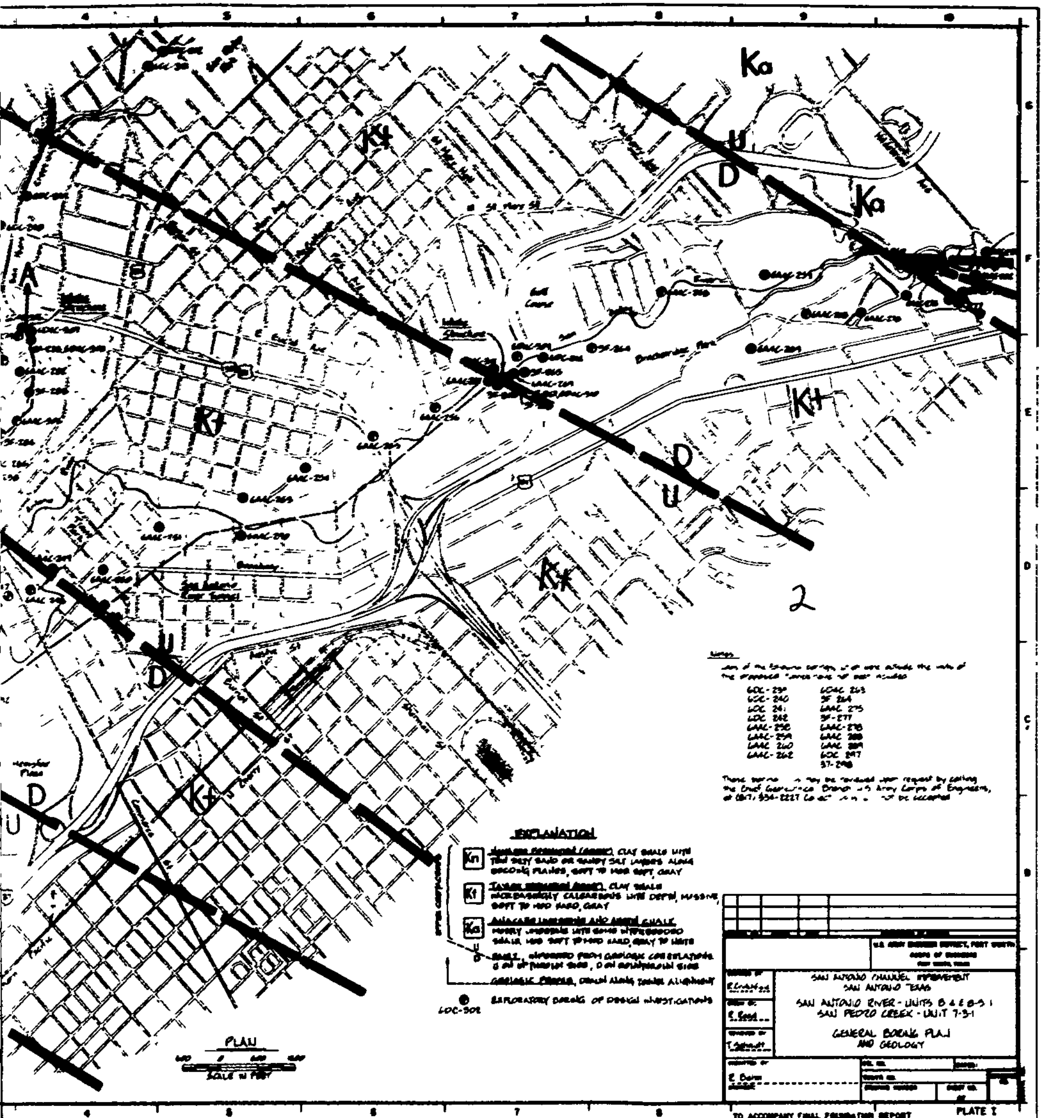
ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	Casing	Geol. Unit	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) e
555.8	80.0					
					Kt	
				12" dia casing		
535.8	100.0					
				Clay Fill		
528.8	107.0					

ENG FORM 1836 PREVIOUS EDITIONS ARE OBSOLETE | PROJECT San Antonio Tunnels | HOLE NO. SP-5

APPENDIX E

Plates (maps)


Kt
Kn
Outlet Structure
EXPLANATION
PLAN
SCALE IN FEET



Ka
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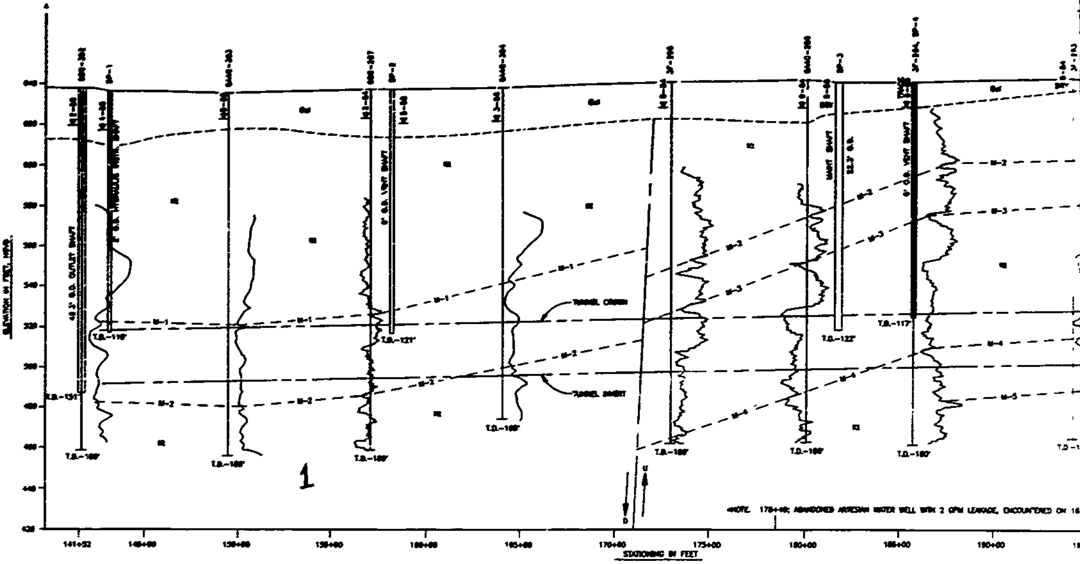
2
EXPLANATION
CLAY SHALE
GEOLOGIC PROFILE
LOC-302
PLAN
SCALE IN FEET
SAN ANTONIO CHANNEL IMPROVEMENT
SAN ANTONIO TEXAS
SAN ANTONIO RIVER - UNITS B 4 & B-3 1
SAN PEDRO CREEK - UNIT 7-3-1
GENERAL BORING PLAN
AND GEOLOGY
TO ACCOMPANY FINAL FOUNDATION REPORT
PLATE I



PROFILE

LEGEND

Qal — OVERBURDEN. GEOLOGICALLY UNCONSOLIDATED DEPOSITS CONSISTING PREDOMINANTLY OF FLUVIATILE LOW TERRACE GRAVELS, SAND, SILT AND CLAYS, WITH SOME RESIDUAL CLAY AND MAN-MADE BACKFILL OR SURFACING, OF QUATERNARY PERIOD.

Kt — TAYLOR FORMATION (GROUP). CLAY SHALE, DARK GRAY TO LIGHT GRAY, SOFT TO MODERATELY HARD WITH OCCASIONAL HARD LENSES IN LIMY ZONES, VARIABLY CALCAREOUS AND BECOMES MORE LIMY IN LOWER FORMATION, MASSIVE WITH ONLY OCCASIONAL JOINTS AND FRACTURES, CRYSTALS OF PYRITE, CALCITE, AND GYPSUM IN PLACES, OCCASIONAL FOSSILS, OF CRETACEOUS PERIOD.

M-2 — STRATIGRAPHIC MARKER. CORRELATION LINES REPRESENTING DISTINCTIVE LIMY HORIZONS WITHIN THE TAYLOR FORMATION WHICH ARE IDENTIFIED IN BOTH ELECTRIC AND LITHOLOGIC LOGS. BEDS ARE DESIGNATED M-1 THROUGH M-5 WITH DEPTH.

FORMATION CONTACT. APPROXIMATE CONTACT BETWEEN OVERBURDEN AND TAYLOR FORMATION AS CORRELATED BETWEEN BORING LOGS.

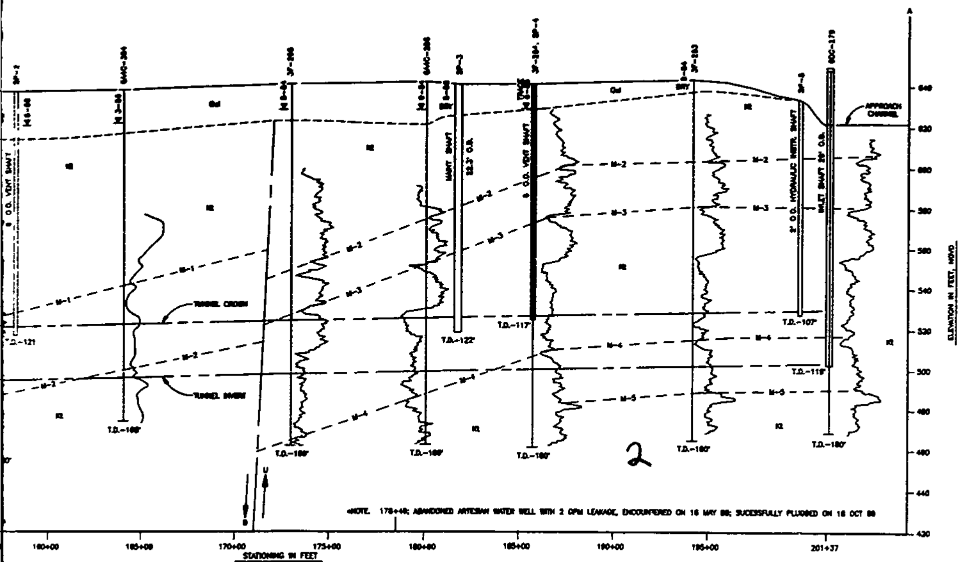
GROUND WATER. WATER LEVEL IN ALLUVIAL AQUIFER ABOVE TAYLOR AQUICLUDE AS MEASURED IN ADJACENT BORING OR SHAFT. NUMBERS GIVE MONTH AND YEAR OF OBSERVATION.

LIMITS OF TUNNEL BORE. SHOWS TUNNEL CROWN AND INVERT

FAULT. APPROXIMATE LOCATION OF FAULT AS INTERPRETED FROM ELECTRIC LOG CORRELATIONS AND TUNNELING LITHOLOGY. ARROWS SHOW DIRECTION OF DISPLACEMENT

SOC-207 — EXPLORATORY BORING WITH ELECTRIC LOG. BORINGS FROM DESIGN INVESTIGATIONS WITH RESISTIVITY LOGS ON BORINGS 302, 303, AND 304 AND GAMMA LOGS ON ALL OTHERS. PREFIX OF BORING NUMBER INDICATES TYPE OF DRILLING AND SAMPLING AS FOLLOWS: A = AUGER, C = CORE BARREL, D = DENISON BARREL, F = FISHTAIL BIT AND NUMBERS PROCEEDING LETTERS GIVE BORING DIAMETER IN INCHES. LITHOLOGIC LOGS OF BORINGS PROVIDED IN APPENDIX F OF FOUNDATION REPORT

SP-? — SHAFTS. SCHEMATIC REPRESENTATION OF EXCAVATED AND DRILLED SHAFTS, WITH SP NUMBER DESIGNATING LITHOLOGIC LOGS OF DRILLED SHAFTS PROVIDED IN APPENDIX D OF FOUNDATION REPORT. GEOLOGIC MAPS OF INLET AND OUTLET SHAFTS ON FOLLOWING PLATES OF THIS SECTION, APPENDIX E.



PROFILE

LEGEND

...CALLY UNCONSOLIDATED DEPOSITS CONSISTING PREDOMINANTLY ...ERRACE GRAVELS, SAND, SILT AND CLAYS, WITH SOME RESIDUAL ... BACKFILL OR SURFACING, OF QUATERNARY PERIOD.

...ROUP), CLAY SHALE, DARK GRAY TO LIGHT GRAY SOFT TO ...TH OCCASIONAL HARD LENSES IN LIMY ZONES, VARIABLY ...COMES MORE LIMY IN LOWER FORMATION, MASSIVE WITH ONLY ...ND FRACTURES, CRYSTALS OF PYRITE, CALCITE, AND GYPSUM ...AL FOSSILS, OF CRETACEOUS PERIOD.

...R, CORRELATION LINES REPRESENTING DISTINCTIVE LIMY HORIZONS ...RMATION WHICH ARE IDENTIFIED IN BOTH ELECTRIC AND LITHOLOGIC ...GNATED M-1 THROUGH M-5 WITH DEPTH.

... APPROXIMATE CONTACT BETWEEN OVERBURDEN AND TAYLOR ...LATED BETWEEN BORING LOGS.

...R LEVEL IN ALLUVIAL AQUIFER ABOVE TAYLOR AQUICLUDE AS ...NT BORING OR SHAFT. NUMBERS GIVE MONTH AND YEAR OF

...E. SHOWS TUNNEL CROWN AND INVERT

FAULT, APPROXIMATE LOCATION OF FAULT AS INTERPRETED FROM ELECTRIC LOG CORRELATIONS AND TUNNELING LITHOLOGY. ARROWS SHOW DIRECTION OF DISPLACEMENT

EXPLORATORY BORING WITH ELECTRIC LOG, BORINGS FROM DESIGN INVESTIGATIONS WITH RESISTIVITY LOGS ON BORINGS 302, 303, AND 304 AND GAMMA LOGS ON ALL OTHERS. PREFIX OF BORING NUMBER INDICATES TYPE OF DRILLING AND SAMPLING AS FOLLOWS: A = AUGER, C = CORE BARREL, D = DENISON BARREL, F = FISHTAIL BIT, AND NUMBERS PROCEEDING LETTERS GIVE BORING DIAMETER IN INCHES. LITHOLOGIC LOGS OF BORINGS PROVIDED IN APPENDIX F OF FOUNDATION REPORT

SHAFTS, SCHEMATIC REPRESENTATION OF EXCAVATED AND DRILLED SHAFTS, WITH SP NUMBER DESIGNATING LITHOLOGIC LOGS OF DRILLED SHAFTS PROVIDED IN APPENDIX D OF FOUNDATION REPORT. GEOLOGIC MAPS OF INLET AND OUTLET SHAFTS ON FOLLOWING PLATES OF THIS SECTION, APPENDIX E.

20 0 20 40
VERTICAL SCALE IN FEET

200 0 200 400
HORIZONTAL SCALE IN FEET

ENGINEERING DIVISION
GEOTECHNICAL BRANCH

U.S. ARMY ENGINEER DISTRICT FORT WORTH
CORPS OF ENGINEERS
FORT WORTH, TEXAS

R. CRUTCHFIELD

K. MILLER

R. CRUTCHFIELD

SAN ANTONIO CHANNEL IMPROVEMENT
SAN ANTONIO, TEXAS

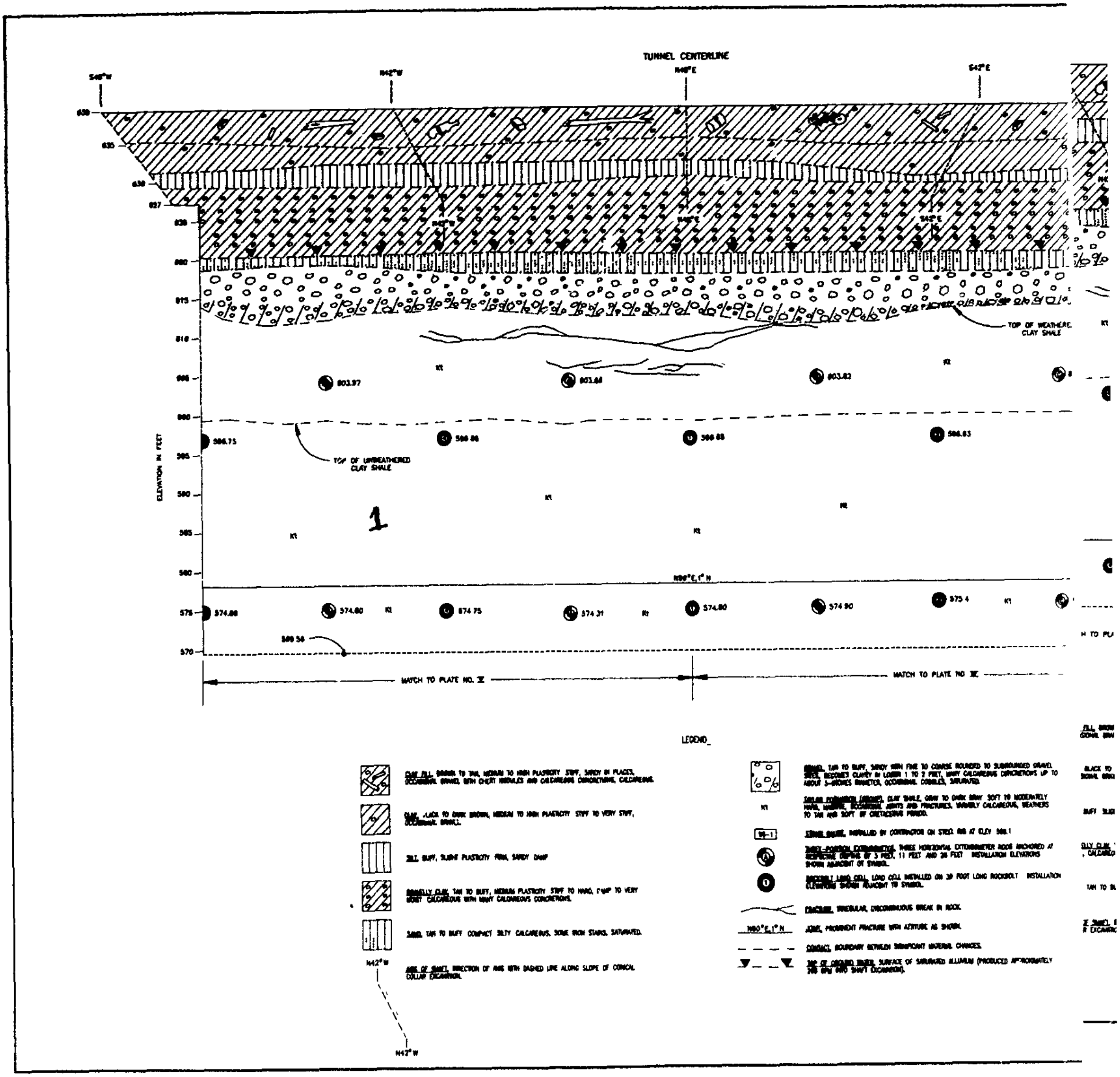
SAN PEDRO CREEK
UNIT 7-3-1

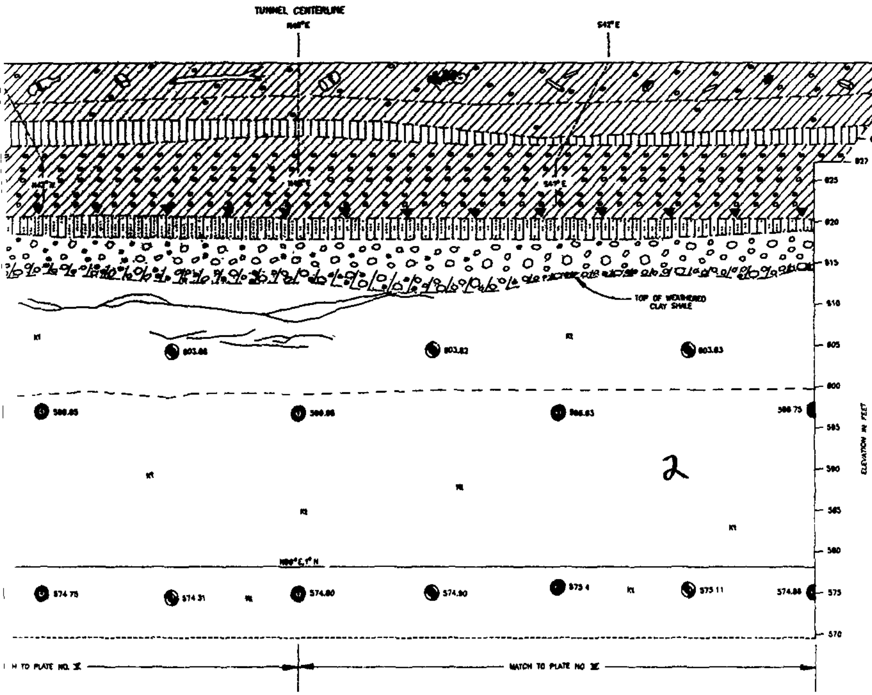
GEOLOGIC PROFILE A-A
TUNNEL ALIGNMENT

KEITH ALLEN

TO ACCOMPANY FINAL FOUNDATION REPORT

PLATE X


TUNNEL CENTERLINE
TOP OF WEATHERED CLAY SHALE
TOP OF UNWEATHERED CLAY SHALE
ELEVATION IN FEET
MATCH TO PLATE NO.
LEGEND
SILT, BUFF, SLIGHT PLASTICITY FIRM, SANDY DAMP
SAND, TAN TO BUFF COMPACT SILTY CALCAREOUS, SOME IRON STAINS, SATURATED.
FRACTURE, IRREGULAR, DISCONTINUOUS BREAK IN ROCK.
CONTACT, BOUNDARY BETWEEN SIGNIFICANT MATERIAL CHANGES.



H TO PLATE NO. IX — MATCH TO PLATE NO IX

LEGEND

FILL, BROWN TO TAN, MEDIUM TO HIGH PLASTICITY, STIFF, SANDY IN PLACES, OCCASIONAL GRAVEL WITH CHERT NODULES AND CALCAREOUS CONCRETIONS, CALCAREOUS.

BLACK TO DARK BROWN, MEDIUM TO HIGH PLASTICITY, STIFF TO VERY STIFF, OCCASIONAL GRAVEL.

BUFF, SLIGHT PLASTICITY, FIRM, SANDY, DAMP

SILTY CLAY, TAN TO BUFF, MEDIUM PLASTICITY, STIFF TO HARD, DAMP TO VERY CALCAREOUS WITH MANY CALCAREOUS CONCRETIONS.

TAN TO BUFF, COMPACT, SILTY, CALCAREOUS, SOME IRON STAINS, SATURATED.

IX SHAFT, DIRECTION OF AXIS WITH DASHED LINE ALONG SLOPE OF CONICAL EXCAVATION

GRAVEL, TAN TO BUFF, SANDY WITH FINE TO COARSE ROUNDED TO SUBROUNDED GRAVEL, BECOMES CLAYEY IN LOWER 1 TO 2 FEET, MANY CALCAREOUS CONCRETIONS UP TO ABOUT 3-INCHES DIAMETER, OCCASIONAL COBBLES, SATURATED.

Kt — TAYLOR FORMATION (UNDIFF.), CLAY SHALE, GRAY TO DARK GRAY, SOFT TO MODERATELY HARD, MASSIVE, OCCASIONAL JOINTS AND FRACTURES, VARIABLY CALCAREOUS, WEATHERS TO TAN AND SOFT, OF CRETACEOUS PERIOD.

SG-1 — STRAIN GAUGE, INSTALLED BY CONTRACTOR ON STEEL RIB AT ELEV 598.1

THREE-POSITION EXTENSOMETER, THREE HORIZONTAL EXTENSOMETER RODS ANCHORED AT RESPECTIVE DEPTHS OF 3 FEET, 11 FEET, AND 20 FEET. INSTALLATION ELEVATIONS SHOWN ADJACENT OF SYMBOL.

ROCKBOLT LOAD CELL, LOAD CELL INSTALLED ON 20 FOOT LONG ROCKBOLT. INSTALLATION ELEVATIONS SHOWN ADJACENT TO SYMBOL.

FRACTURE, IRREGULAR, DISCONTINUOUS BREAK IN ROCK.

N90° E, 1° N — JOINT, PROMINENT FRACTURE WITH ATTITUDE AS SHOWN.

CONTACT, BOUNDARY BETWEEN SIGNIFICANT MATERIAL CHANGES.

TOP OF GROUND WATER, SURFACE OF SATURATED ALLUVIUM (PRODUCED APPROXIMATELY 300 GPM INTO SHAFT EXCAVATION).

NOTE

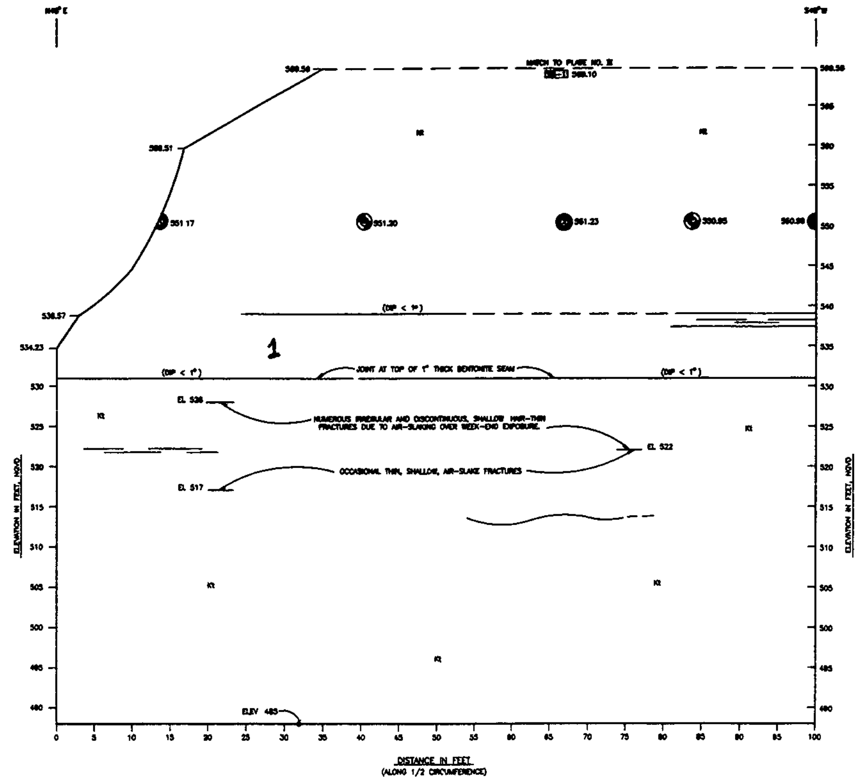
THIS MAP IS A FOLD-OUT PROFILE SHOWING THE FULL SHAFT CIRCUMFERENCE IN THE UPPER CYLINDRICAL SECTION OF THE EXCAVATION. PLATES IX AND X SHOW THE "ELBOW" EXCAVATION WHERE THE SHAFT ENLARGES TOWARD THE TRANSITION TO THE TUNNEL. THE TRANSITION EXCAVATION IS SHOWN ON PLATE XI.

5 0 5 10
SCALE IN FEET

ENGINEERING DIVISION GEOTECHNICAL BRANCH	U.S. ARMY ENGINEER DISTRICT, FORT WORTH CORPS OF ENGINEERS FORT WORTH, TEXAS
MAPPED BY: K. CRUTCHFIELD	SAN ANTONIO CHANNEL IMPROVEMENT SAN ANTONIO TEXAS
C.A.D.D. BY: K. MILLER	SAN PEDRO CREEK
REVIEWED BY: K. CRUTCHFIELD	OUTLET SHAFT GEOLOGY
SUBMITTED BY: KEITH ALLEN	SOL. NO. DATED: CONTR. NO. DRAWING NUMBER SHEET NO. OF

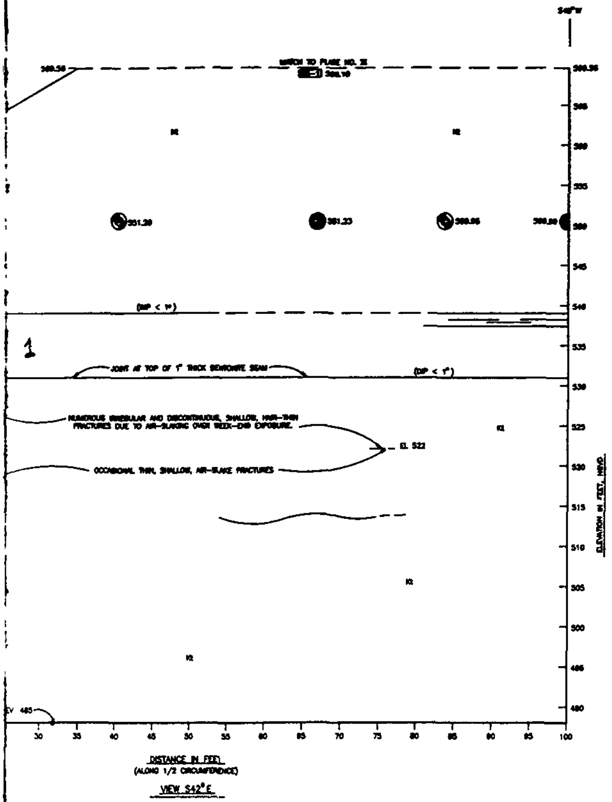
TO ACCOMPANY FINAL FOUNDATION REPORT

PLATE IX



551 17
551.20
551.23
534.23
(DIP < 1°)
1
JOINT AT TOP OF 1" THICK BENTONITE SEAM
EL 517
EL 522
NUMEROUS IRREGULAR AND DISCONTINUOUS, SHALLOW HAIR-THIN FRACTURES DUE TO AIR-SLAKING OVER WEEK-END EXPOSURE.
OCCASIONAL THIN, SHALLOW, AIR-SLAKE FRACTURES
ELEVATION IN FEET, NGVD
Kt
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
DISTANCE IN FEET
(ALONG 1/2 CIRCUMFERENCE)

VIEW S42°E



2

NOTES.

1 THIS MAP IS A FOLD-OUT PROFILE SHOWING HALF OF THE SHAFT CIRCUMFERENCE SE OF TUNNEL CENTERLINE.

2. FOR LEGEND, SEE PLATE NO. II.

0 5 10
SCALE IN FEET

ENGINEERING DIVISION
GEOTECHNICAL BRANCH

U.S. ARMY ENGINEER DISTRICT FORT WORTH
CORPS OF ENGINEERS
FORT WORTH, TEXAS

SAN ANTONIO CHANNEL IMPROVEMENT
SAN ANTONIO, TEXAS

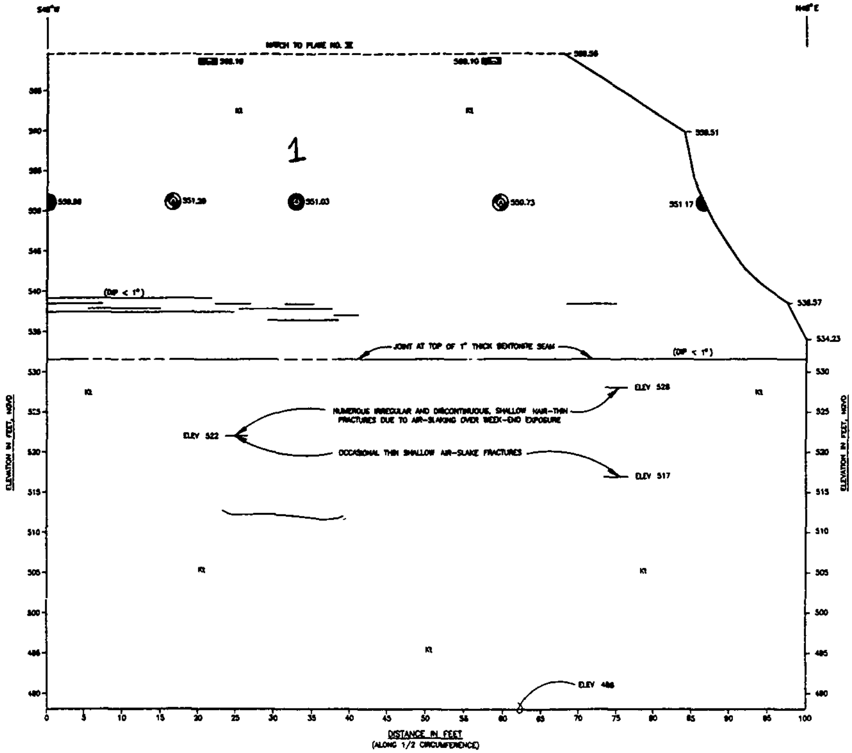
SAN PEDRO CREEK
UNIT 7-3-1

OUTLET SHAFT GEOLOGY

KEITH ALLEN

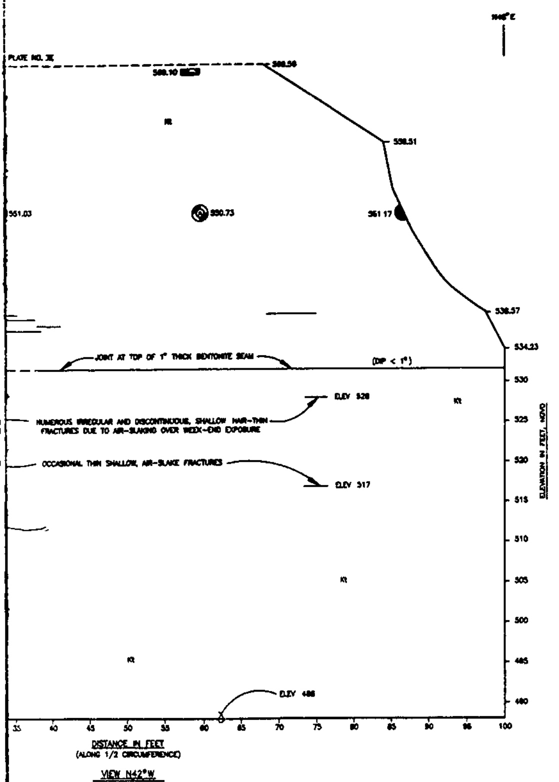
TO ACCOMPANY FINAL FOUNDATION REPORT

PLATE IX



1
351.29
351.03
550.73
351 17
(DIP < 1°)
JOINT AT TOP OF 1" THICK BENTONITE SEAM
ELEV 528
NUMEROUS IRREGULAR AND DISCONTINUOUS, SHALLOW HAIR-THIN FRACTURES DUE TO AIR-SLAKING OVER WEEK-END EXPOSURE
ELEV 522
OCCASIONAL THIN SHALLOW AIR-SLAKE FRACTURES
ELEV 517
ELEVATION IN FEET, NGVD
DISTANCE IN FEET
(ALONG 1/2 CIRCUMFERENCE)

VIEW N42°W



2

NOTES.

1. THIS MAP IS A FOLD-OUT PROFILE SHOWING HALF OF THE SHAFT CIRCUMFERENCE NW OF TUNNEL CENTERLINE.
2. FOR LEGEND, SEE PLATE NO. X

SCALE IN FEET

ENGINEERING DIVISION
GEOTECHNICAL BRANCH

U.S. ARMY ENGINEER DISTRICT FORT WORTH
CORPS OF ENGINEERS
FORT WORTH, TEXAS

SAN ANTONIO CHANNEL IMPROVEMENT
SAN ANTONIO, TEXAS

SAN PEDRO CREEK
UNIT 7-3-1

OUTLET SHAFT GEOLOGY

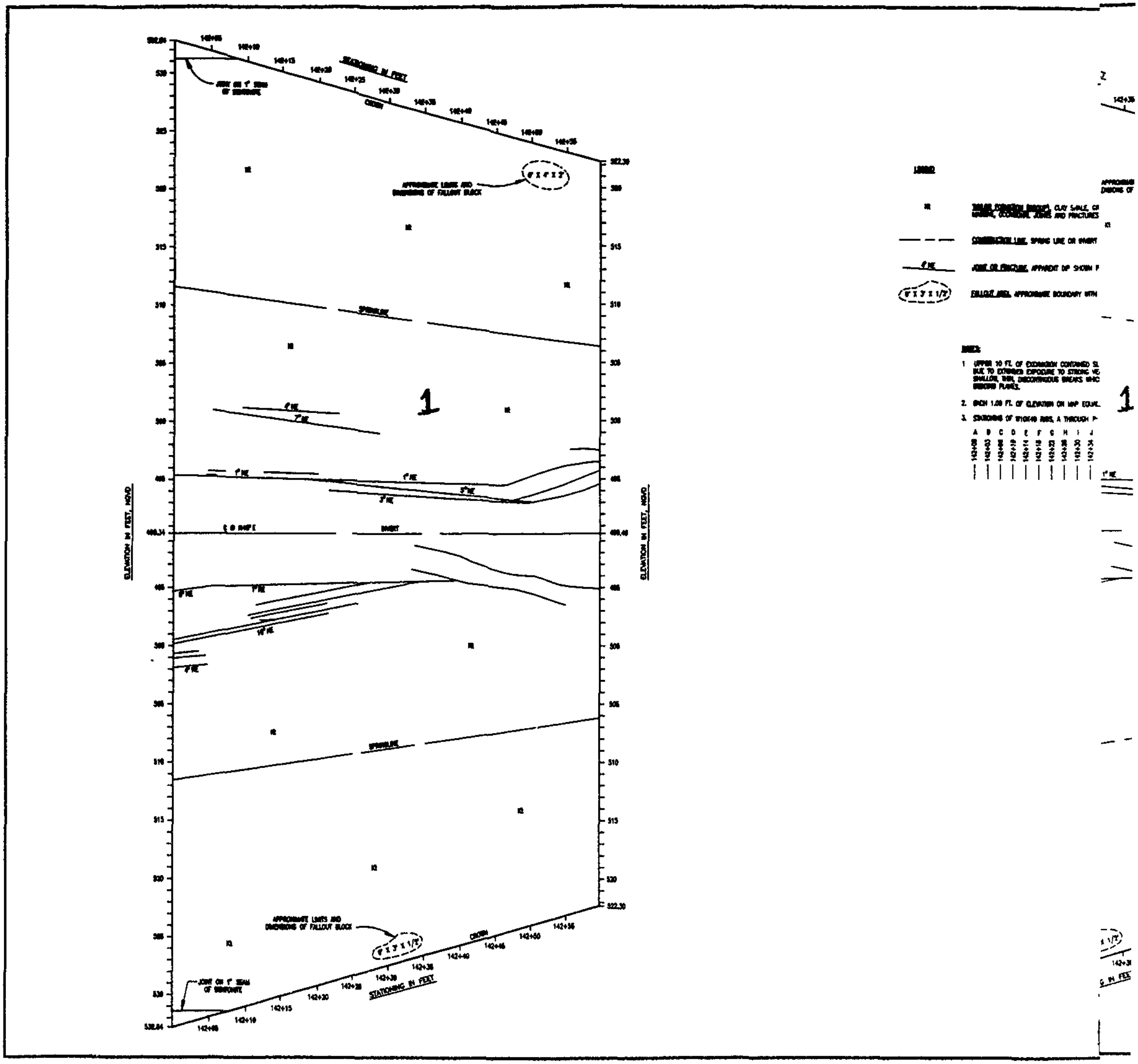
R. CRUTCHFIELD
C.A.D.D. BY K. MILLER
R. CRUTCHFIELD

SUBMITTED BY: KEITH ALLEN

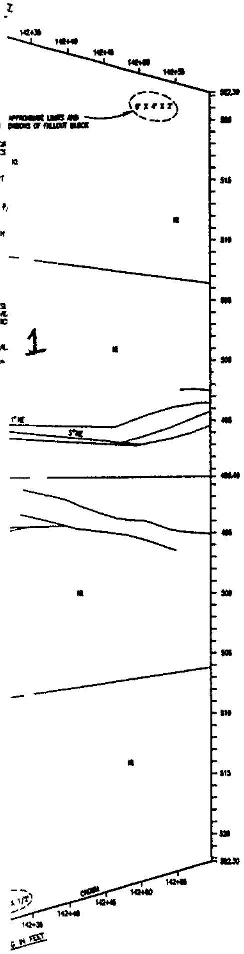
SOL. NO. | DATED:
CONTR. NO.
SHEET NO. OF

TO ACCOMPANY FINAL FOUNDATION REPORT

PLATE X



STATIONING IN FEET
CROWN
SPRINGLINE
INVERT
ELEVATION IN FEET, NGVD
APPROXIMATE LIMITS AND DIMENSIONS OF FALLOUT BLOCK
1
LEGEND
CONSTRUCTION LINE, SPRING LINE OR INVERT
JOINT OR FRACTURE, APPARENT DIP SHOWN
FALLOUT AREA, APPROXIMATE BOUNDARY WITH
NOTES:
2. EACH 1.00 FT. OF ELEVATION ON MAP EQUAL



LEGEND

Kd — DEL RIO FORMATION (KDR): CLAY SHALE, GRAY TO DARK GRAY, SOFT TO MODERATELY SOFT, MASSIVE, OCCASIONAL JOINTS AND FRACTURES, VARIABLY CALCAREOUS, OF CRETACEOUS PERIOD.

CONSTRUCTION LINE, SPRING LINE OR INVERT AS SHOWN.

JOINT OR FRACTURE, APPARENT DIP SHOWN PARALLEL TO CENTERLINE.

FALLOUT AREA, APPROXIMATE BOUNDARY WITH BLOCK DIMENSIONS AS SHOWN.

2

NOTES:

1. UPPER 10 FT. OF EXCAVATION CONTAINED SLAKING AND DESICCATION FRACTURES THROUGHOUT DUE TO EXTENDED EXPOSURE TO STRONG VENTILATION AIR FLOW. THESE FRACTURES WERE SHALLOW, THIN, DISCONTINUOUS BREAKS WHICH OCCURRED MOSTLY ALONG NEARLY HORIZONTAL BEDDING PLANES.
2. EACH 1.00 FT. OF ELEVATION ON MAP EQUALS 1.57 FT. OF CURVED SURFACE IN EXCAVATION.
3. STATIONING OF W10X49 RIBS, A THROUGH P:

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

HORIZONTAL SCALE IN FEET

ENGINEERING DIVISION
GEOTECHNICAL BRANCH

U.S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
FORT WORTH, TEXAS

MAPPED BY: R. CRUTCHFIELD
C.A.D.D. BY: K. MILLER
REVIEWED BY: R. CRUTCHFIELD
SUBMITTED BY: KEITH ALLEN, RESIDENT ENGINEER

SAN ANTONIO CHANNEL IMPROVEMENT
SAN ANTONIO, TEXAS

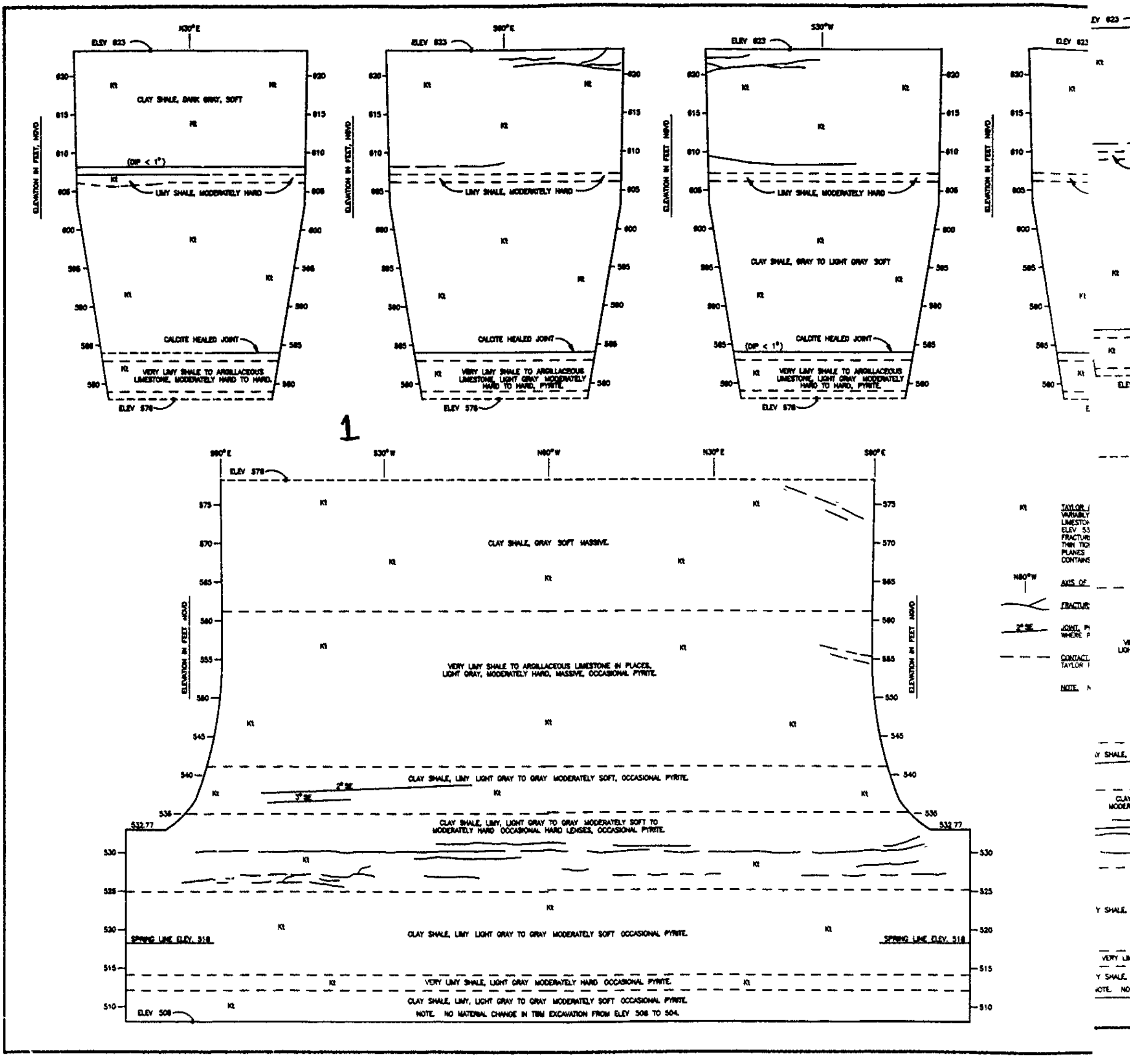
SAN PEDRO CREEK
UNIT 7-3-1

OUTLET SHAFT GEOLOGY
TRANSITION

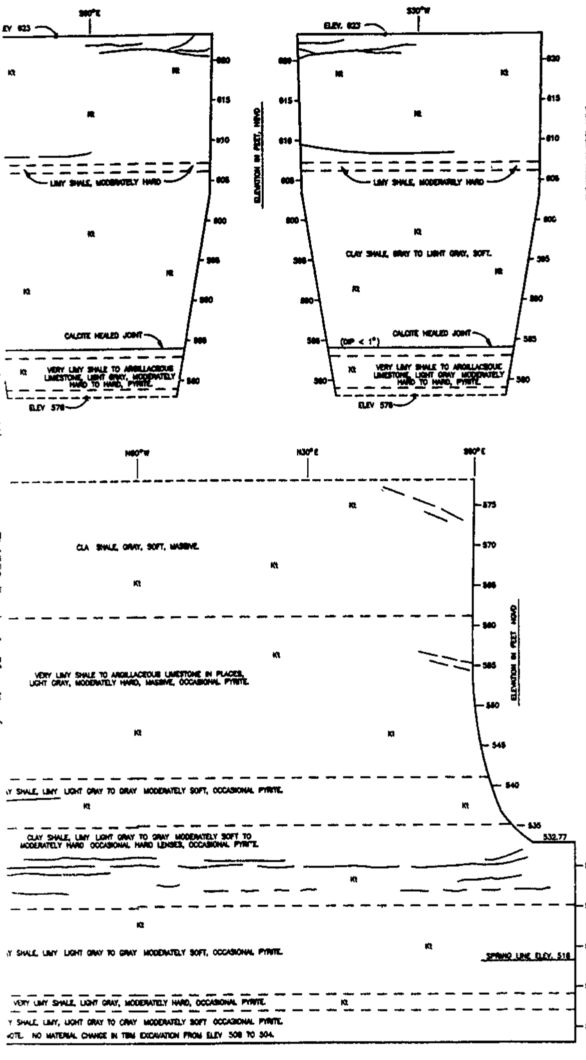
SOL. NO. | DATE:
CONTR. NO.
DRAWING NUMBER | SHEET NO. OF | REFERENCE NO.

TO ACCOMPANY FINAL FOUNDATION REPORT

PLATE 3C



ELEV 623
N30°E
S60°E
S30°W
CLAY SHALE, DARK GRAY, SOFT
(DIP < 1°)
LIMY SHALE, MODERATELY HARD
CALCITE HEALED JOINT
VERY LIMY SHALE TO ARGILLACEOUS LIMESTONE, MODERATELY HARD TO HARD.
VERY LIMY SHALE TO ARGILLACEOUS LIMESTONE, LIGHT GRAY, MODERATELY HARD TO HARD, PYRITE.
CLAY SHALE, GRAY TO LIGHT GRAY SOFT
ELEV 578
ELEVATION IN FEET, NGVD
1
N60°W
CLAY SHALE, GRAY SOFT MASSIVE.
VERY LIMY SHALE TO ARGILLACEOUS LIMESTONE IN PLACES, LIGHT GRAY, MODERATELY HARD, MASSIVE, OCCASIONAL PYRITE.
CLAY SHALE, LIMY LIGHT GRAY TO GRAY MODERATELY SOFT, OCCASIONAL PYRITE.
2° SE
3° SE
CLAY SHALE, LIMY, LIGHT GRAY TO GRAY MODERATELY SOFT TO MODERATELY HARD OCCASIONAL HARD LENSES, OCCASIONAL PYRITE.
532.77
SPRING LINE ELEV. 518
VERY LIMY SHALE, LIGHT GRAY MODERATELY HARD OCCASIONAL PYRITE.
CLAY SHALE, LIMY, LIGHT GRAY TO GRAY MODERATELY SOFT OCCASIONAL PYRITE.
NOTE. NO MATERIAL CHANGE IN TBM EXCAVATION FROM ELEV 508 TO 504.
ELEV 508
Kt
AXIS OF
FRACTURE
JOINT
CONTACT
NOTE.



2

LEGEND

Kt — TAYLOR FORMATION (GROUP). CLAY SHALE, DARK GRAY TO LIGHT GRAY VARIABLY CALCAREOUS WITH LIMY LAYERS GRADATIONAL TO ARGILLACEOUS LIMESTONE, SOFT TO MODERATELY HARD WITH OCCASIONAL HARD LENSES FROM ELEV 536 TO 525, GENERALLY MASSIVE WITH ONLY A FEW JOINTS AND FRACTURES, DISCONTINUOUS FRACTURES BETWEEN ELEV 532 AND 528 WHERE THIN TIGHT BREAKAGE SURFACES OCCURRING PREDOMINANTLY ALONG BEDDING PLANES (THE LIMY HARDER ZONES WERE EXCAVATED WITH A HYDRAULIC RAM). CONTAINS OCCASIONAL PYRITE CRYSTALS AND FOSSILS, OF CRETACEOUS PERIOD

N60°W — AXIS OF SHAFT, DIRECTION OF VIEW ALONG AXIS PERPENDICULAR TO MAP

FRACTURE, IRREGULAR, DISCONTINUOUS BREAK IN ROCK.

2° SE — JOINT, PROMINENT FRACTURE, WITH APPARENT DIP AS SHOWN, DASHED LINE WHERE PROJECTED.

CONTACT, BOUNDARY BETWEEN ZONES OF MATERIAL VARIATIONS WITHIN THE TAYLOR FM. (Kt) MOSTLY CHANGES IN CALCAREOUS CONTENT AND HARDNESS.

NOTE. NO GROUND WATER ENCOUNTERED.

5 0 5 10
SCALE IN FEET

ENGINEERING DIVISION
GEOTECHNICAL BRANCH

U.S. ARMY ENGINEER DISTRICT FORT WORTH
CORPS OF ENGINEERS
FORT WORTH, TEXAS

SAN ANTONIO CHANNEL IMPROVEMENT
SAN ANTONIO TEXAS

SAN PEDRO CREEK
UNIT 7-3-1

INLET SHAFT GEOLOGY

R. CRUTCHFIELD
K. MILLER
R. CRUTCHFIELD

KEITH ALLEN

SOL. NO. | DATE:
CONTR. NO.
SHEET NO. OF

TO ACCOMPANY FINAL FOUNDATION REPORT

PLATE 3K

APPENDIX F

Boring Logs (design investigations)

DL-1

Hole No. [illegible]

DRILLING LOG	DIVISION [illegible]
INSTALLATION	[illegible]
SHEET 1 OF 1 SHEETS	
1. PROJECT	San Pedro Creek
2. LOCATION	
3. DRILLING AGENCY	Corps of Engineers
4. HOLE NO.	DH-223
5. NAME OF DRILLER	Tim Carl
6. DIRECTION OF HOLE	☒ VERTICAL ☐ INCLINED ___ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN	23.0'
8. DEPTH DRILLED INTO ROCK	
9. TOTAL DEPTH OF HOLE	23.0'
10. SIZE AND TYPE OF BIT	6" auger
11. DATUM FOR ELEVATION SHOWN (TBM or MSL)	
12. MANUFACTURER'S DESIGNATION OF DRILL	[illegible]
13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN	DISTURBED 7 / UNDISTURBED [illegible]
14. TOTAL NUMBER CORE BOXES	
15. ELEVATION GROUND WATER	[illegible]
16. DATE HOLE	STARTED 27 [illegible] / COMPLETED [illegible]
17. ELEVATION TOP OF HOLE	[illegible]
18. TOTAL CORE RECOVERY FOR BORING	%
19. SIGNATURE OF INSPECTOR	Robert H. Dean

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
			0.0' to 3.5' FILL – 0.0' to 2.0' CLAY, medium to high plasticity, stiff, dry to slightly moist, dark brown, roots.		A	1. Dry after 1 hour [illegible] covered.
			2.0' to 3.5' Medium plasticity, stiff to very stiff, dry to slightly moist, brown & yellow brown, gravelly, scattered cobbles, (possible boulders in plug)		B	2. Samples: A. 0.0' to [illegible] B. 2.0' to 3.5' C. 3.5' to [illegible] D. 6.1' to 11.0' E. 11.0' to [illegible] F. 16.0' to [illegible] G. [illegible]
	10.0		Primary? – – – – – – – – – –		C	
			3.5' to 23.0' CLAY – 3.5' to 6.1' Medium to high plasticity, very stiff, slightly moist, brown w/ rusty brown mottling.		D	3. All material [illegible]
			6.1' to 20.0' High plasticity, very stiff, slightly moist, mixed yellow brown, brown & gray to 6.5'. Becomes more yellow to gold brown from 6.5'. More grayish from 9.2'. Becomes more gold brown from 11.0' 16.0'. Scattered gravel from 14.[illegible]'		E	4. Gravel [illegible] fragments.
	20.0		Becomes slightly silty, mottled gray, brown, & yellow brown from 16.0'.		F	
625.[illegible]			20.0' to 23.0' Medium to high plasticity, very stiff to moderately hard, moist, dark gray, slightly silty.		G	
			– – – – T.D. 23.0' – – – –			

ENG FORM MAR 71 1836 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT) | PROJECT San Pedro Creek | HOLE NO.

Hole No. 6DC-235

DRILLING LOG	DIVISION 3..D	INSTALLATION Fw..	SHEET 1 of 2 SHEETS
1. PROJECT SAN ANTONIO CHANNEL IMPROVEMENT UNIT VII-3 SAN PEDRO CREEK		10. SIZE AND TYPE OF BIT STAGE, 6"O BARREL & CALGARY	
2. LOCATION (Coordinates or Station) STA 16+00 95 50' R		11. DATUM FOR ELEVATION SHOWN (TBM or MSL)	
3. DRILLING AGENCY USCE-C		12. MANUFACTURER'S DESIGNATION OF DRILL FAILING 1500	
4. HOLE NO. (As shown on drawing title and file number) 6DC-235		13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN	DISTURBED 14 / UNDISTURBED 2
5. NAME OF DRILLER BROWER & SUTS		14. TOTAL NUMBER CORE BOXES 6	
6. DIRECTION OF HOLE [X] VERTICAL [ ] INCLINED ____ DEG. FROM VERT.		15. ELEVATION GROUND WATER SEE REMARKS	
		16. DATE HOLE	STARTED 18 MAY 81 / COMPLETED 19 MAY 81
7. THICKNESS OF OVERBURDEN 22.0'		17. ELEVATION TOP OF HOLE 643.1'	
8. DEPTH DRILLED INTO ROCK 33.3'		18. TOTAL CORE RECOVERY FOR BORING 100 %	
9. TOTAL DEPTH OF HOLE 55.3'		19. SIGNATURE OF INSPECTOR Richard K. Colman	

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
643.1'	00'		00' to 01' ASPHALT		A	1 SAMPLES
			01' to 07' BASE COURSE/GRAVEL TAN, DRY, MED DENSE COARSE GRAIN; SANDY		B	JARS: A 01'-07' B 07'-20' C 20-40' D 40'-60' E 60 65' F 65'-80' G 80'-100 H @ 120' I @ 135 J 135'-145 K 145-155' L 155'-175' M 175'-200' N 200-220' O 220 230' P @ 248 Q @ 289 R @ 339' S @ 398 T @ 409' U @ 459' V @ 519
			07' to 13.5' FILL/CLAY		C	
			00'-2.0' BRN, SLI MOIST, SLI STIFF, LOW-MED PLASTICITY, CALC, SCAT CaCO3 STREAKS, SANDY, GRAVELLY WITH FINE TO MED GRAVEL		D	
					E	
					F	
					G	
	10		2.0'-4.0' YELLOW-BONE TAN, MOIST, MED STIFF, MED HIGH PLASTICITY, CALC, WHITE CaCO3 NODULES & DEPOSITS; DEBRIS (CONCRETE FRAGS)		DB-1	
					H	
					DB 2	
			4.0'-6.5' BRN, MOIST, MED STIFF, MED-HIGH PLASTICITY, CALC, ABUNDANT CaCO3 NODULES, SOME SCAT GRAVEL		I	
					J	
					K	DENISONS DB-1 10.0'-12.0 DB 2 12.0'-13.5'
			6.0'-6.5' POCKET OF WHITE COARSE CaCO3		L	
			6.5-8.0' BRN, SLI MOIST SLI STIFF, LOW PLASTICITY, VERY SANDY, FEW SCAT GRAVEL & DEBRIS		M	CARTONS C1 23.9-24.8 C2 28.9 29.8 C3 33.9-34.8 C4 37.9 38.0 C5 40.0'-40.9' C6 45.0'-45.9' C7 51.0'-51.9'
	20		8.0-10.0' DK BRN-GRAY, MOIST, MED STIFF, HIGH PLASTICITY, FEW SCAT FINE CaCO3 NODULES & FINE GRAVEL		N	
	22.0'				O	
			10.0'-12.0 DK BRN-GRAY, MOIST, VERY STIFF, HIGH PLASTICITY, ABUNDANT DEBRIS (BRICK & CONCRETE FRAGS)	23.6	C1 P	2 DRILLING 8" AUGER 00-20 SOFT AUGERING FROM 07'-20 SET 8" CASING TO 20 6" DENISON 20'-40' NOTE DEBRIS NOTED FROM 20-40' PROBABLY FROM CASING OF LINE RUNNING ALONGSIDE HOLE 8" AUGER 40'-80 DUE TO DEBRIS IN FILL 6" DENISON 80-175'; WITH LITTLE TO NO WATER RETURN LITTLE RECOVERY 80'-100' BRICK & CONCRETE DEBRIS ON TOP OF DENISONS 1 & 2 TOO MUCH GRAVEL FOR GOOD SAMPLES FROM 135'-175' 8" AUGER 175'-230' SET 8" CASING TO 238' CLEANED OUT WITH AUGER TO 236' 6" CORING 236'-553 LEFT 03 CORE IN HOLE BAILED BORING TO APPROX 49' PULLED
			12.0'-13.5' DK BRN-GRAY, MOIST, STIFF, HIGH PLASTICITY, FEW SCAT FINE CaCO3 NODULES, SCAT DEBRIS (HOOK)	1.03'	BOX 1	
				27.8		
			13.5' to 14.5'	1.02	R C2	
	30		GRAVEL WHITE, MED LOOSE, FINE & COARSE GRAIN, POORLY GRADED IN CLAY as above	31.8		
			14.5' to 17.5' CLAY		BOX 2	
			14.5'-15.5' DK BRN-GRAY, MOIST, VERY STIFF, HIGH PLASTICITY, SCAT CaCO3 NODULES & CaCO3 GRAVEL	1.00	R C3	
				35.8'		
			15.5'-17.5' YELLOW-BRN, MOIST, STIFF, HIGH PLASTICITY, WHITE CaCO3 DEPOSITS, CaCO3 NODULES, CaCO3 GRAVEL, GRAVELLY	1.00	BOX 3	
				38.8	C4 S	
	40					

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT) | PROJECT SAN PEDRO CREEK | HOLE NO. 6DC 235

Hole No. LDC-235

DRILLING LOG — DIVISION: SWD — INSTALLATION: FW — SHEET 2 OF 2 SHEETS

1. PROJECT: SAN ANTONIO CHANNEL IMPROVEMENT UNIT VII-3 SAN PEDRO CREEK
2. LOCATION (Coordinates or Station): STA 160+60 C/L 50' R
3. DRILLING AGENCY: USCE-C
4. HOLE NO. (As shown on drawing title and file number): LDC-235
5. NAME OF DRILLER: BREWERE SUITS
6. DIRECTION OF HOLE: [X] VERTICAL [ ] INCLINED ______ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN: 22.0'
8. DEPTH DRILLED INTO ROCK: 33.3'
9. TOTAL DEPTH OF HOLE: 55.3'
10. SIZE AND TYPE OF BIT: 8" AUGER, 6" D-BARREL CORE BARREL
11. DATUM FOR ELEVATION SHOWN (TBM or MSL):
12. MANUFACTURER'S DESIGNATION OF DRILL: FAILING 1500
13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED N — UNDISTURBED 2
14. TOTAL NUMBER CORE BOXES: 6
15. ELEVATION GROUND WATER: SEE REMARKS
16. DATE HOLE: STARTED 18 MAY 81 — COMPLETED 19 MAY 81
17. ELEVATION TOP OF HOLE: 642.1'
18. TOTAL CORE RECOVERY FOR BORING: 100 %
19. SIGNATURE OF INSPECTOR: Deborah L. Colvin

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
			17.5' to 22.0 GRAVEL	100	US 4	CASING GROUTED BORING 2 DAYS AFTER DRILLING COMPLETED
			17.5'-20.0' TAN, MED LOOSE, WELL-GRADED, PREDOMINANTLY CaCO3, IN YELLOW BRN CLAY, CLAYEY	42.8'	Box 4	3 WATER LEVEL
			20.0'-22.0' TAN, MED LOOSE, FINE & COARSE GRAIN, MOD GRADED, PREDOMINANTLY CaCO3, IN GRAY & LT BRN COARSE CaCO3 SANDY CLAY	100 / 46.8	US 6	2 HRS AFTER BAILING WATER LEVEL WAS @ 19.5'; 24 HRS AFTER BAILING WATER LEVEL WAS @ 18.5'; 48 HRS AFTER BAILING WATER LEVEL WAS @ 18.5'
			22.0' to 55.3' SHALE	603	Box 5	NOTE OBSERVED WATER ENTERING HOLE @ GRAVEL ZONE 13.5'-14.5'
	50		22.0-23.8' GREEN & YELLOW BRN, VERY HIGHLY WEATHERED TO STIFF CLAY CONSISTENCY, VERY SANDY	50.8	CT V	
			23.8'-32.8' YELLOW-BRN & GREEN-GRAY, MOD SOFT, VERY HIGHLY WEATHERED, FEW SCAT HARD CaCO3 STRINGERS & THIN SEAMS, SANDY	100	Box 6	4 BASE OF WEATHERING: BASE OF WEATHERING @ 40.5'
586.8'	55.3'		32.8'-36.1' YELLOW-BRN, MOD SOFT, VERY HIGHLY WEATHERED, SCAT THIN HARD CaCO3 SEAMS & STRINGERS, VERY SANDY	55.3'		
	60		36.1'-40.5' YELLOW-BRN & GRAY, MOD SOFT, HIGHLY WEATHERED, FEW SCAT HARD CaCO3 STRINGERS, SANDY			
			40.5'-55.3' DK GRAY, MOD HARD, UNWEATHERED, FEW SCAT HARD CaCO3 STRINGERS; SANDY, SCAT LENSES & POCKETS OF CLAY SHALE			
	70		TD 55.3'			
	80					

ENG FORM 1836 MAR 71 — PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT) — PROJECT: SAN PEDRO CREEK — HOLE NO. LDC 235

DL-4

Hole No. 6DC-236

DRILLING LOG	DIVISION	INSTALLATION Ft Wort.	SHEET 1 OF 2 SHEETS

1. PROJECT San Antonio Channel Improvement	10. SIZE AND TYPE OF BIT *
2. LOCATION (Coordinates or Station) San Pedro Creek, sta. 165 + 90, o/s 65' L	11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
3. DRILLING AGENCY USCE	12. MANUFACTURER'S DESIGNATION OF DRILL Failing 1500
4. HOLE NO. (As shown on drawing title and file number) 236	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN — DISTURBED 7 — UNDISTURBED -
5. NAME OF DRILLER Mullins	14. TOTAL NUMBER CORE BOXES 5
6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED ___ DEG. FROM VERT.	15. ELEVATION GROUND WATER ***
	16. DATE HOLE — STARTED 18 May 81 — COMPLETED 19 May 81
7. THICKNESS OF OVERBURDEN 22'	17. ELEVATION TOP OF HOLE 641.3'
8. DEPTH DRILLED INTO ROCK 30'	18. TOTAL CORE RECOVERY FOR BORING 98 %
9. TOTAL DEPTH OF HOLE 52'	19. SIGNATURE OF INSPECTOR Robert A. McKay Jr

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
			0.0 to 0.4		A	* **Drilling**
			SAND - fine, dry, brown, calc, silty, Fill.		B	0.0 to 23' - 8" auger set 23' csng clean out to 23.5' 23.5 to 52' - 6" core.
			0.4 to 15.6			
			CLAY			***
			0.4 to 8.5 - FILL - high to med. plasticity, stiff, damp, dark brown, calc, sandy & gravelly, bricks.		C	Hole bailed after drilling, 24 hr check *
	10'		8.5 to 13.8 - high plast, stiff, moist, dark gray, calc, sl sandy & gravelly.		D	**Jars** A. 0.0 to 0.4 B. 0.4 to 5.4 C. 5.4 to 8.5 D. 8.5 to 13.8 E. 13.8 to 15.6 F. 15.6 to 20.6 G. 20.6 to 22.0 H. 22.0 to 23.5
			13.8 to 15.6 - high plast, med stiff/stiff, moist, yellow brown and gray and white, very limey, gravel nodules.		E	
			15.6 to 22.0			
			GRAVEL - coarse to fine and round, wet, white with yellow brown clay, lime nodules = 100%.		F	**Cartons** 1. 23.5 - 24.5 2. 30.3 to 31.7 3. 38.0 - 39.0 4. 39.7 - 40.7 5. 46.0 - 47.0 6. 50.6 - 51.6
	20'		22.0 to 51.6		G	
			CLAY SHALE - **ARENACEOUS** - weather stained yellow brown and gray till 38.8, then unweathered dark gray massive, soft to med soft (rx classi), calc, silty, thin sand and silt seams scattered.		H	Base of weathering * 38.8'.
					1 Box 1	
				100		
	30			100	2 Box 2	
				100	Box 3	
	40			100	3	
					4	

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT) PROJECT HOLE NO.

DL-5

Hole No. 6D-236

DRILLING LOG	DIVISION SWD	INSTALLATION Ft Worth	SHEET 2 OF 2 SHEETS

1. PROJECT San Antonio Channel Improvement
2. LOCATION (Coordinates or Station) San Pedro Creek, Sta 165+90 5 west
3. DRILLING AGENCY
4. HOLE NO. (As shown on drawing title and file number)
5. NAME OF DRILLER
6. DIRECTION OF HOLE ☐ VERTICAL ☐ INCLINED ______ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN
8. DEPTH DRILLED INTO ROCK
9. TOTAL DEPTH OF HOLE
10. SIZE AND TYPE OF BIT
11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
12. MANUFACTURER'S DESIGNATION OF DRILL
13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN | DISTURBED | UNDISTURBED
14. TOTAL NUMBER CORE BOXES
15. ELEVATION GROUND WATER
16. DATE HOLE | STARTED | COMPLETED
17. ELEVATION TOP OF HOLE
18. TOTAL CORE RECOVERY FOR BORING %
19. SIGNATURE OF INSPECTOR Robert A McVey Jr.

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
				0/AL	4	
				G o.2	Box 4	
				L o 0	5	
					Box 5	
	50					
				L o 4	6	

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT) | PROJECT | HOLE NO.

Hole No. LDC-237

DRILLING LOG	DIVISION: SWD	INSTALLATION: FWD	SHEET 1 OF 2 SHEETS

1. PROJECT	SAN ANTONIO CHANNEL IMPROVEMENT UNIT VII-3 SAN PEDRO CREEK
2. LOCATION (Coordinates or Station)	SEE REMARKS
3. DRILLING AGENCY	USCE-C
4. HOLE NO. (As shown on drawing title and file number)	LDC-237
5. NAME OF DRILLER	SUITS
6. DIRECTION OF HOLE	☒ VERTICAL ☐ INCLINED ____ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN	15.0'
8. DEPTH DRILLED INTO ROCK	33.0
9. TOTAL DEPTH OF HOLE	48.0'
10. SIZE AND TYPE OF BIT	10" AUGER, 6" D. BARREL CORE
11. DATUM FOR ELEVATION SHOWN (TBM or MSL)	
12. MANUFACTURER'S DESIGNATION OF DRILL	FAILING 1500
13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN	DISTURBED: 7 / UNDISTURBED: 2
14. TOTAL NUMBER CORE BOXES	6
15. ELEVATION GROUND WATER	SEE REMARKS
16. DATE HOLE	STARTED: 27 MAY 81 / COMPLETED: 28 MAY 81
17. ELEVATION TOP OF HOLE	TP 642.1'
18. TOTAL CORE RECOVERY FOR BORING	100%
19. SIGNATURE OF INSPECTOR	[illegible]

ELEVATION (a)	DEPTH (b)	LEGEND (c)	CLASSIFICATION OF MATERIALS (Description) (d)	% CORE RECOVERY (e)	BOX OR SAMPLE NO. (f)	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) (g)
642.1'	0.0'		**0.0' TO 0.1'** ASPHALT		A	1 SAMPLES
			0.1' TO 1.2' BASE COURSE/GRAVEL TAN, DRY, MED DENSE, FINE & COARSE GRAIN, VERY SANDY		B	JARS: A 0.1'-1.2'; B 1.2'-1.8'; C 1.8'-6.8'; D 6.8'-8.0'; E @ 10.0'; F @ 11.5'; G 11.5'-15.0'; H 15.0'-16.0'; I 16.0'-19.0'
			1.2' TO 9.0' FILL/CLAY		C	
			1.2'-1.8' DK BRN, DAMP, MED STIFF, MED PLASTICITY, MANY FINE $CaCO_3$ NODULES, SCAT COARSER $CaCO_3$ NODULES, SCAT MED GRAVEL		D	DENISONS: DB 1 8.0'-10.0'; DB 2 10.0'-11.5'
	10		1.8'-6.8' AS ABOVE, WITH ABUNDANT FINE TO COARSE MOD GRADED GRAVEL		DB-1	
			6.8'-9.0' DK GRAY-BRN, MOIST, STIFF, MED-HIGH PLASTICITY, ABUNDANT FINE $CaCO_3$ NODULES; SCAT FINE GRAVEL, SCAT DEBRIS (BRICK & GLASS FRAGS)		E	CARTONS: C1 21.5'-22.4'; C2 28.1'-29.0'; C3 32.4'-33.3'; C4 38.6'-39.5'; C5 46.0'-46.9'
	15.0'		**9.0' TO 11.5'** CLAY		DB 2	
			9.0'-10.0' LT GRAY, VERY MOIST, MED STIFF, MED PLASTICITY, SANDY, ABUNDANT $CaCO_3$ NODULES, SCAT SHELLS, SCAT GRAVEL, HIGHLY CALC		F	
	20		10.0'-11.5' GREENE YELLOW-BRN, VERY MOIST, MED STIFF, HIGH PLASTICITY, ABUNDANT $CaCO_3$ DEPOSITS, ABUNDANT MED TO COARSE GRAVEL, SCAT $CaCO_3$ NODULES, VERY GRAVELLY	21.0'	G	2 DRILLING: 10" AUGER 0.0'-8.0' SET 8" CASING TO 8.0' 6" DENISON 8.0'-11.5' PULLED CASING 10" AUGER 11.5'-19.0' SET 8" CASING TO 19.0' 8" AUGER CLEAN OUT 19.0'-21.0' 6" CORING 21.0'-48.0' BAILED BORING CLOSE TO BOTTOM
			11.5' TO 15.0' GRAVEL TAN & WHITE, VERY MOIST, DENSE, MED TO COARSE GRAIN, PREDOMINANTLY $CaCO_3$, IN GREEN-GRAY HIGH PLASTICITY LIMEY CLAY, VERY CLAYEY	100	H	
				25.0'	I	
				100	C1	
	30			29.5'	BOX 1	
			15.0' TO 48.0' SHALE	100	BOX 2	3 WATER LEVEL: AFTER PULLING CASING & AUGERING TO 15.0', WATER LEVEL WAS @ 10.2'. OBSERVED WATER ENTERING HOLE @ 10.2' 30 MINUTES LATER WATER LEVEL WAS @ 9.8'. WHILE BAILING HOLE WATER WAS GUSHING IN FROM CASED PORTION OF HOLE. BY THE TIME CASING WAS PULLED WATER LEVEL WAS @ 10.0' 24 HRS AFTER BAILING WATER LEVEL WAS @ 9.4'
			15.0'-16.0' YELLOW-BRN & GREEN-GRAY, SOFT, VERY HIGHLY WEATHERED, SCAT $CaCO_3$ NODULES, SCAT FINE GRAVEL, SLI SANDY	33.0'	C2	
				100	C3	
				37.0'	BOX 3	
	40			100	BOX 4	
					C4	

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT)

PROJECT: SAN PEDRO CREEK | HOLE NO. LDC-237

DL-7

Hole No. LOC 237

DRILLING LOG — Division: SWD	Installation: FWD — Sheet 2 of 2 sheets
1. Project: SAN ANTONIO CHANNEL IMPROVEMENT UNIT VII-3 SAN PEDRO CREEK	10. Size and type of bit: [illegible]
2. Location (Coordinates or Station): ** SEE REMARKS	11. Datum for elevation shown (TBM or MSL):
3. Drilling agency: USCE-C	12. Manufacturer's designation of drill: FAILING 1500
4. Hole No. (As shown on drawing title and file number): LOC-237	13. Total no. of overburden samples taken: Disturbed 7; Undisturbed 2
5. Name of driller: SUITS	14. Total number core boxes: 6
6. Direction of hole: ☑ Vertical ☐ Inclined ___ Deg. from vert.	15. Elevation ground water: ** SEE REMARKS
7. Thickness of overburden: 15.0'	16. Date hole: Started 27 MAY 81; Completed 28 MAY 81
8. Depth drilled into rock: 33.0	17. Elevation top of hole: 642.1'
9. Total depth of hole: 48.0'	18. Total core recovery for boring: 100 %
	19. Signature of inspector: [signature]

Elevation a	Depth b	Legend c	Classification of Materials (Description) d	% Core Recovery e	Box or Sample No. f	Remarks (Drilling time, water loss, depth of weathering, etc. if significant) g
			16.0'-21.0' YELLOW-BRN & GREEN-GRAY, SOFT, VERY HIGHLY WEATHERED, FEW SCAT FINE $CaCO_3$ NODULES, SLI SANDY	41.0' / 100	Box 5	* BASE OF WEATHERING: BASE OF WEATHERING @ 38.7'
			21.0'-32.1': YELLOW-BRN & GREEN-GRAY, MOD SOFT, HIGHLY WEATHERED, SCAT $CaCO_3$ POCKETS, SANDY	43.0' / 101	Box 6 CS	** 5 OFFSET: LOCATION MOVED APPROXIMATELY 270' NORTH OF STA 170+30 % 50'L. NEW LOCATION PLANE COORDINATES. X 2,160,376 Y 378,805. OFFSET FROM THESE NEW COORDINATES WAS 10' TO THE NORTH & 4' TO THE WEST DUE TO PARKING CONDITIONS & TREES. ELEVATION USED REFERS TO THAT GIVEN FOR ABOVE X,Y COORDINATES
594.1'	48.0'		32.1'-38.7' DK GRAY & YELLOW-BRN, MOD SOFT, MOD WEATHERED, SANDY	48.0		
	50		38.7'-48.0' DK GRAY, MOD HARD, UNWEATHERED, SLI SANDY			
			TD 48.0'			
	60					
	70					
	80					

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT) — Project: SAN PEDRO CREEK — Hole No. LOC-237

Hole No 6D?-23?

DRILLING LOG	DIVISION SWD	INSTALLATION Ft W..h	SHEET 1 of 2 SHEETS

1. PROJECT	San Antonio Channel Improvement
2. LOCATION (Coordinates or Station)	San Pedro Creek, sta. 179 + 00 o/s 50' R
3. DRILLING AGENCY	USCE
4. HOLE NO. (As shown on drawing title and file number)	238
5. NAME OF DRILLER	Mulling
6. DIRECTION OF HOLE	☒ VERTICAL ☐ INCLINED ____ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN	20.3
8. DEPTH DRILLED INTO ROCK	31.2
9. TOTAL DEPTH OF HOLE	51.5
10. SIZE AND TYPE OF BIT	
11. DATUM FOR ELEVATION SHOWN (TBM or MSL)	
12. MANUFACTURER'S DESIGNATION OF DRILL	Failing 1500
13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN	DISTURBED 6 / UNDISTURBED -
14. TOTAL NUMBER CORE BOXES	***
15. ELEVATION GROUND WATER	***
16. DATE HOLE	STARTED 21 May 81 / COMPLETED 22 May 81
17. ELEVATION TOP OF HOLE	6457'
18. TOTAL CORE RECOVERY FOR BORING	100 %
19. SIGNATURE OF INSPECTOR	Robert A. McVey Jr

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
			0.0 to 0.1 - Asphalt.		A	* Drilling 0.0 to 23' - 10" auger - gravelly - set 23' core. clean out to 24'. 24 to - 6" core.
			0.1 to 6.7 GRAVEL - coarse to fine and angular to round, dry, brown till 1.7', then pale brown with pockets of brown, sandy and clayey, bricks.		B	*** Making water @ 15'. Hole bailed. 24 hr check @ 12.8'. 3 hr check @ 13.4
	10'		6.7 to 20.3 CLAY 6.7 to 13.2 - high/med. plasticity, med stiff, moist, dark grayish brown, calc, sandy & gravelly, FILL.		C D	Jars A. 0.1 to 1.7 B. 1.7 to 6.7 C. 6.7 to 11.7 D. 11.7 to 13.2 E. 13.2 to 15.0 F. 15.0 to 20.3 G. 20.3 to 24.0
			13.2 to 20.3 - med/high plast, med stiff, moist till 15.0', then wet and soft, sandy and gravelly, rl cobbly, mostly olive with some light grey and yellowish brown.		E F	Too gravelly for denison bbl.
	20'		20.3 to 51.5 ARENACIOUS SHALE - - 20.3 to 37.0 - weather stained yellowish brown and light grey to grey, soft to mod soft(rx class), massive, calc, dry.		G 1	Cartons 1. 24.4 to 25.3 2. 31.7 to 32.7 3. 37.4 to 38.4 4. 43.1 to 44.1 5. 49.2 to 50.0 Base of weathering @ 37'.
	30'		37.0 to 51.5 - unweathered dark grey, very sandy/silty seams scattered, otherwise as above.		Box 1 2 Box 2 Box 3 3	Core stored @ Lackland AFB.

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT) | PROJECT | HOLE NO

DL-9

Hole No. 6DC-23δ

DRILLING LOG	DIVISION SWD	INSTALLATION Ft Worth	SHEET 2 OF 2 SHEETS

1. PROJECT San Antonio Channel Improvement
2. LOCATION (Coordinates or Station) San Pedro Creek
3. DRILLING AGENCY USCE
4. HOLE NO. (As shown on drawing title and file number) 6DC-28
5. NAME OF DRILLER
6. DIRECTION OF HOLE ☐ VERTICAL ☐ INCLINED ______ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN
8. DEPTH DRILLED INTO ROCK
9. TOTAL DEPTH OF HOLE
10. SIZE AND TYPE OF BIT
11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
12. MANUFACTURER'S DESIGNATION OF DRILL
13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN | DISTURBED | UNDISTURBED
14. TOTAL NUMBER CORE BOXES
15. ELEVATION GROUND WATER
16. DATE HOLE | STARTED | COMPLETED
17. ELEVATION TOP OF HOLE
18. TOTAL CORE RECOVERY FOR BORING %
19. SIGNATURE OF INSPECTOR Clark McKey

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	40				Box 4 [4]	
					Box 5 [5]	
	50					

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT) | PROJECT | HOLE NO.

DL-109

Hole No. 6DC-279

DRILLING LOG	DIVISION SWD	INSTALLATION Ft Worth	SHEET 1 of 5 SHEETS
1. PROJECT San Pedro Creek, San Antonio, Tx.		10. SIZE AND TYPE OF BIT	
2. LOCATION (Coordinates or Station)		11. DATUM FOR ELEVATION SHOWN (TBM or MSL)	
3. DRILLING AGENCY USCE		12. MANUFACTURER'S DESIGNATION OF DRILL Gardner Denver 1500	
4. HOLE NO. (As shown on drawing title and file number) 6DC-279		13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN	DISTURBED 0 UNDISTURBED 0
5. NAME OF DRILLER Reese of Hilyard drilling		14. TOTAL NUMBER CORE BOXES 37	
6. DIRECTION OF HOLE [X] VERTICAL [ ] INCLINED ___ DEG. FROM VERT.		15. ELEVATION GROUND WATER	
7. THICKNESS OF OVERBURDEN see **		16. DATE HOLE	STARTED 26 March 84 COMPLETED 9 Apr 1 84
8. DEPTH DRILLED INTO ROCK see **		17. ELEVATION TOP OF HOLE 651.0'	
9. TOTAL DEPTH OF HOLE 180'		18. TOTAL CORE RECOVERY FOR BORING 97 %	
		19. SIGNATURE OF INSPECTOR Robert McVey	

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
			10.0 to 21.8 SHALE - weathered, yellow brown, massive, mostly blocky structure with a few scattered plastic seams, soft to moderately soft (rock classification), calcareous Open 45 degree joint or fracture (no slicks) from 12.4 to 12.8', a few healed (tight) fractures scattered throughout			* Drilling 0.0 to 10' - rockbit, 10 to 180' - 6" carbo-oid bit ** This hole was started by government drill crew. See log by Jack Stokes for information on top ten feet. Hole cased to ten feet and grouted in by above crew
	10'		21.8 to 180.0 SHALE - unweathered, dark gray, massive, lime content increases with depth until 35', then remains consistent until T.D., moderately soft until 35', then moderately hard (rock classification), chemical odor after 65' to T.D., green glauconitic sand within shale matrix from 152.5 to 155.0'	Lost 1.6'	Box 1	*** Hole to be bailed at a later date
				L3.0 0.3' is actual Loss	2	All core recovery was wrapped in cheesecloth and sealed with wax before being placed in core boxes
	20'			Gain 3.0	3	Hole location Hole is 87.5' at a bearing of S 41 E from reference marker SP-200
				L2.5' 2.5 is actual Loss G0.3	4	
	30'			L0.0 L1.5' 1.4 AL	5	
				G1.5'	6	
	40'			L1.9'	7	

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT) | PROJECT | HOLE NO.

DL-110

Hole No 6DC-279

DRILLING LOG	DIVISION SVD	INSTALLATION Ft. 4..ch	SHEET 2 OF 5 SHEETS

1. PROJECT San Pedro Creek, San Antonio, Tx.	10. SIZE AND TYPE OF BIT
2. LOCATION (Coordinates or Station)	11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
3. DRILLING AGENCY USCE	12. MANUFACTURER'S DESIGNATION OF DRILL
4. HOLE NO. (As shown on drawing title and file number) 6DC-279	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN — DISTURBED — UNDISTURBED
5. NAME OF DRILLER	14. TOTAL NUMBER CORE BOXES
6. DIRECTION OF HOLE ☐ VERTICAL ☐ INCLINED ____ DEG. FROM VERT.	15. ELEVATION GROUND WATER
	16. DATE HOLE — STARTED — COMPLETED
7. THICKNESS OF OVERBURDEN	17. ELEVATION TOP OF HOLE
8. DEPTH DRILLED INTO ROCK	18. TOTAL CORE RECOVERY FOR BORING %
9. TOTAL DEPTH OF HOLE 180'	19. SIGNATURE OF INSPECTOR Robert McVey

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	40'			609	7	
				100	8	
				105	9	
	50'			646		
				104	10	
				Lost 5' Regained 5'	11	
	60'					
				100	12	
				100	13	
	70'					
				104	14	
				606	15	
	80'				16	

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT) — PROJECT — HOLE NO.

DL-111

Hole No 6DC-279

DRILLING LOG	DIVISION SWD	INSTALLATION Ft Worth	SHEET 3 OF 5 SHEETS

1. PROJECT San Pedro Creek, San Antonio, Tx.	10. SIZE AND TYPE OF BIT
2. LOCATION (Coordinates or Station)	11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
3. DRILLING AGENCY USEE	12. MANUFACTURER'S DESIGNATION OF DRILL
4. HOLE NO. (As shown on drawing title and file number)	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED / UNDISTURBED
5. NAME OF DRILLER	14. TOTAL NUMBER CORE BOXES
6. DIRECTION OF HOLE ☐ VERTICAL ☐ INCLINED ____ DEG. FROM VERT.	15. ELEVATION GROUND WATER
	16. DATE HOLE: STARTED / COMPLETED
7. THICKNESS OF OVERBURDEN	17. ELEVATION TOP OF HOLE
8. DEPTH DRILLED INTO ROCK	18. TOTAL CORE RECOVERY FOR BORING %
9. TOTAL DEPTH OF HOLE 180'	19. SIGNATURE OF INSPECTOR Robert McVey

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
				L 0 4	16	
					17	
				L 1 0'		
	90'				18	
				L 3' @ 3 " actual Loss	19	
				C 3 9'		
	100'			L 0 9	20	
				C 0 9	21	
				C 4 4	22	
	110'			C 1 2	23	
				L 0 2	24	
	120'				25	

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT) PROJECT HOLE NO.

60

DL-112

Hole No. 6DC-279

DRILLING LOG	DIVISION SWD	INSTALLATION L. North	SHEET 4 of 5 SHEETS

1. PROJECT San Pedro Creek, San Antonio, Tx.
2. LOCATION (Coordinates or Station)
3. DRILLING AGENCY USCE
4. HOLE NO. (As shown on drawing title and file number) 6DC-279
5. NAME OF DRILLER
6. DIRECTION OF HOLE ☐ VERTICAL ☐ INCLINED ____ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN
8. DEPTH DRILLED INTO ROCK
9. TOTAL DEPTH OF HOLE 180'
10. SIZE AND TYPE OF BIT
11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
12. MANUFACTURER'S DESIGNATION OF DRILL
13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN | DISTURBED | UNDISTURBED
14. TOTAL NUMBER CORE BOXES
15. ELEVATION GROUND WATER
16. DATE HOLE | STARTED | COMPLETED
17. ELEVATION TOP OF HOLE
18. TOTAL CORE RECOVERY FOR BORING %
19. SIGNATURE OF INSPECTOR Robert McVey

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
				41	25	
				42	26	
				61		
	130'				27	
				66		
					28	
				100		
	140'				29	
				62	30	
				65	31	
	150'					
				63	32	
				100	33	
	160'					

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT) | PROJECT | HOLE NO.

DL-113

Hole No. 6RC-279

DRILLING LOG		INSTALLATION Ft Worth	SHEET 5 OF 5 SHEETS

1. PROJECT: San Pedro Creek, San Antonio, Tx.

3. DRILLING AGENCY: USCE

4. HOLE NO.: 6RC-279

9. TOTAL DEPTH OF HOLE: 180' T.D.

19. SIGNATURE OF INSPECTOR: Robert McVey

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS
					33	
				100	34	
				100	35	
	170'			100	36	
				100	37	
	180'					

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT) | PROJECT | HOLE NO

Hole No. 6DC-279

DRILLING LOG

DIVISION	SWD
INSTALLATION	FWD
SHEET	1 of 1 SHEETS
1. PROJECT	San Pedro Tunnel, San Antonio, Tx.
2. LOCATION (Coordinates or Station)	See Remarks Column # 6
3. DRILLING AGENCY	USCE-C
4. HOLE NO. (As shown on drawing title and file number)	6DC-279
5. NAME OF DRILLER	T. Smith
6. DIRECTION OF HOLE	☒ Vertical ☐ Inclined ___ Deg. from Vert.
7. THICKNESS OF OVERBURDEN	1.0'±
8. DEPTH DRILLED INTO ROCK	9.0'±
9. TOTAL DEPTH OF HOLE	10.0'
10. SIZE AND TYPE OF BIT	6" Carboloy
11. DATUM FOR ELEVATION SHOWN (TBM or MSL)	
12. MANUFACTURER'S DESIGNATION OF DRILL	Failing 1500
13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN	Disturbed: 1 · Undisturbed: 0
14. TOTAL NUMBER CORE BOXES	See Remarks Column
15. ELEVATION GROUND WATER	See Remarks Column
16. DATE HOLE	Started: 29 Feb. 84 · Completed: 1 Mar. 84
17. ELEVATION TOP OF HOLE	650'±
18. TOTAL CORE RECOVERY FOR BORING	N/A %
19. SIGNATURE OF INSPECTOR	Jack R. [signature]

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	0.0		0.0' to 1.0'±		A	1. NOTE: No free water entering boring during drilling. Boring cased off with 8" PVC pipe & grouted in place to 10.'
	1.0		CLAY: Medium plasticity; brown; hard; dry-damp, calcareous, with scattered gravel		B	
			1.0'± to 10.0'		DB 1 (4.5?)	
			CLAY SHALE: Medium-high plasticity; very highly weathered down to highly weathered from 3.0'±; yellowish brown & olive brown, soft, damp; calcareous, silty down to 3.0'±		DB 2 (4.5?)	
					DB 3 (4.5?)	2. Jar Samples. A: 0.0' - 1.0 B: 1.0' - 2.6' C: 6.6'
					DB 4 (4.5?)	
	10.0					3 Denison Samples: DB 1: 2.6' - 4.6' 2: 4.6' - 6.6' 3: 6.6' - 8.6' 4: 8.6 - 10.0'
						4. Drilling 10" Flight Auger: 0.0' - 2.6' 6" Denison Barrel: 2.6' - 10.0' Note: Boring was bailed & 8" PVC pipe was placed to 10.0' & grouted in place
	20					5. Note: Boring is to be deepened with 6" core barrel at a later date. A metal cover was placed over boring for protection
						6 Note: Boring off-set approx 60' S along alignment due to traffic hazard
	30					

ENG FORM 1836 MAR 71 — PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT)

PROJECT: San Pedro Tunnel — HOLE NO. 6DC-279

DL-115

Hole No. 6AHC-280

DRILLING LOG	380	Ft. W...h	Sheet 1 of 5 sheets

Project: San Pedro Creek, San Antonio, Tx.	
Location:	
Drilling agency: USCE	Gardner Denver 1500
Hole no.: 6AHC-280	Total no. of overburden samples taken: 2 / 9
Name of driller: Reese	Total number core boxes: 13
Direction of hole: [x] Vertical [ ] Inclined	Elevation ground water: ---
	Date hole: Started 19 April 86 – Completed 24 April 86
Thickness of overburden: 4.0	Elevation top of hole: 163.2'
Depth drilled into rock: 176.0	Total core recovery for boring: 100 %
Total depth of hole: 180.0	Signature of inspector: Robert McVay

Elevation (a)	Depth (b)	Legend (c)	Classification of materials (d)	% Core recovery (e)	Box or sample no. (f)	Remarks (g)
			0.0 to 0.5' - Concrete.		A	Drilling
			0.5 to 1.0 - Base Gravels - coarse to fine, damp, red brown, very sandy.		B	0.0 to 0.5' - 7 7/8" rockbit. 0.5 to 2' - 11" dragbit. 2 to 11' - 10" auger. 11' to 120' - 7 7/8" rockbit. 120 to 180' - 4" carbon core.
			1.0 to 4.0 CLAY - high plasticity, soft to medium stiff, moist, dark olive, gravels scattered within, possibly an extremely weathered shale.		C	
	10'		4.0 to 11.0 SHALE - badly weathered, a soft clay consistency, moist, some good shale structure after 8', yellow brown, some light gray, massive, silty, lime nodules and concentrations.		D	*** No water level taken. A bentonitic grout mixture sealed up hole after drilling and E-log.
					Rockbit	Hole recorded with resistivity, caliper, and gamma logs by contractor. All 4" recovered core was wrapped with cheesecloth and sealed with heated wax.
			11 to 120' - rockbit, unweathered dark gray @ 34'.			
	20'		120 to 180) SHALE - unweathered, dark gray and white, massive, calc, chemical odor, moderately soft to mod. hard (rock classification), limey throughout, pyrite scattered, sl. fossiliferous. Slightly glauconitic(sand) from 163 to 164.8, green glauconite sand scattered from 164.8 to 165.3', some pyrite. Becomes very limey after 150'.			Hole location: 78.8' with bearing of S26°E from SP-P00. Driller called unweathered at 34'.
	30					Jars A. 0.5 to 1.0 B. 1.0 to 4.0 C. 4.0 to 8.0 D. 8.0 to 11.0
	40'					

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT) | PROJECT | HOLE NO.

DL-116

Hole No. 6AAC-2PD

DRILLING LOG	DIVISION SWD	INSTALLATION Ft Worth	SHEET 2 of 5 SHEETS

1. PROJECT San Pedro Creek, San Antonio, Tx.
2. LOCATION (Coordinates or Station)
3. DRILLING AGENCY USCE
4. HOLE NO. (As shown on drawing title and file number) 6AAC-2PD
5. NAME OF DRILLER Mecoe
6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED ______ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN
8. DEPTH DRILLED INTO ROCK
9. TOTAL DEPTH OF HOLE 170.3'
10. SIZE AND TYPE OF BIT
11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
12. MANUFACTURER'S DESIGNATION OF DRILL
13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN | DISTURBED | UNDISTURBED
14. TOTAL NUMBER CORE BOXES
15. ELEVATION GROUND WATER
16. DATE HOLE | STARTED | COMPLETED
17. ELEVATION TOP OF HOLE
18. TOTAL CORE RECOVERY FOR BORING %
19. SIGNATURE OF INSPECTOR Robert McKey

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
					Rock bit	
	50'					
	60'					
	70					
	80					

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT) | PROJECT | HOLE NO.

DL-117

Hole No. 6A4C-280

DRILLING LOG	DIVISION SWD	INSTALLATION Ft Worth	SHEET 3 OF 5 SHEETS

1. PROJECT San Pedro Creek, San Antonio, Tx.	10. SIZE AND TYPE OF BIT
2. LOCATION (Coordinates or Station)	11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
3. DRILLING AGENCY USCE	12. MANUFACTURER'S DESIGNATION OF DRILL
4. HOLE NO. (As shown on drawing title and file number) 6A4C-280	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN — DISTURBED — UNDISTURBED
5. NAME OF DRILLER Reese	14. TOTAL NUMBER CORE BOXES
6. DIRECTION OF HOLE ☐ VERTICAL ☐ INCLINED ___ DEG. FROM VERT.	15. ELEVATION GROUND WATER
7. THICKNESS OF OVERBURDEN	16. DATE HOLE — STARTED — COMPLETED
8. DEPTH DRILLED INTO ROCK	17. ELEVATION TOP OF HOLE
9. TOTAL DEPTH OF HOLE 180.3	18. TOTAL CORE RECOVERY FOR BORING %
	19. SIGNATURE OF INSPECTOR

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	90'				Rock bit	
	100'					
	110					
	120'					

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT) | PROJECT | HOLE NO.

DL-118

Hole No. 6AWC-280

DRILLING LOG	DIVISION SWD	INSTALLATION ¢ North	SHEET 4 OF 5 SHEETS

1. PROJECT San Pedro Creek, San Antonio, Tx.	10. SIZE AND TYPE OF BIT
2. LOCATION (Coordinates or Station)	11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
3. DRILLING AGENCY U'F	12. MANUFACTURER'S DESIGNATION OF DRILL
4. HOLE NO. (As shown on drawing title and file number) 6AWC-280	13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN / DISTURBED / UNDISTURBED
5. NAME OF DRILLER Reese	14. TOTAL NUMBER CORE BOXES
6. DIRECTION OF HOLE ☐ VERTICAL ☐ INCLINED ___ DEG. FROM VERT.	15. ELEVATION GROUND WATER
7. THICKNESS OF OVERBURDEN	16. DATE HOLE / STARTED / COMPLETED
8. DEPTH DRILLED INTO ROCK	17. ELEVATION TOP OF HOLE
9. TOTAL DEPTH OF HOLE 180.3'	18. TOTAL CORE RECOVERY FOR BORING %
	19. SIGNATURE OF INSPECTOR Robert McVay

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
				Lost 00	Box 1	
					2	
	130'				3	
				Loo	4	
	140'				5	
				Loo	6	
	150'				7	
				Loo	8	
	160'				9	

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT) PROJECT HOLE NO.

DL-119

DRILLING LOG	DIVISION SWD	INSTALLATION Fort Worth	SHEET 5 of 5 SHEETS

Hole No. 6A6C-2B0

1. PROJECT San Pedro Creek, San Antonio, Tx.	10. SIZE AND TYPE OF BIT
2. LOCATION (Coordinates or Station)	11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
3. DRILLING AGENCY USCE	12. MANUFACTURER'S DESIGNATION OF DRILL
4. HOLE NO. (As shown on drawing title and file number) 6A6C-2B0	13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN — DISTURBED — UNDISTURBED
5. NAME OF DRILLER Reese	14. TOTAL NUMBER CORE BOXES
6. DIRECTION OF HOLE ☐ VERTICAL ☐ INCLINED ____ DEG. FROM VERT.	15. ELEVATION GROUND WATER
	16. DATE HOLE — STARTED — COMPLETED
7. THICKNESS OF OVERBURDEN	17. ELEVATION TOP OF HOLE
8. DEPTH DRILLED INTO ROCK	18. TOTAL CORE RECOVERY FOR BORING
9. TOTAL DEPTH OF HOLE 180.3	19. SIGNATURE OF INSPECTOR Robert McVay

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
					9	
				100	10	
	170'				11	
				100'	12	
					13	
	180'					

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT) | PROJECT | HOLE NO.

DL-120

Hole No. 6A4C-281

DRILLING LOG	DIVISION SWD	INSTALLATION Ft ...th	SHEET 1 of 5 SHEETS

1. PROJECT: San Pedro Creek, San Antonio, Tx.	10. SIZE AND TYPE OF BIT: *
2. LOCATION (Coordinates or Station)	11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
3. DRILLING AGENCY: USCE	12. MANUFACTURER'S DESIGNATION OF DRILL: Falling 1500
4. HOLE NO. (As shown on drawing title and file number): 6A4C-281	13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: DISTURBED 3; UNDISTURBED 0
5. NAME OF DRILLER: Reese of Hilyard drilling.	14. TOTAL NUMBER CORE BOXES: 13
6. DIRECTION OF HOLE: [X] VERTICAL [ ] INCLINED ___ DEG. FROM VERT.	15. ELEVATION GROUND WATER: ***
	16. DATE HOLE: STARTED 26 April 84; COMPLETED 1 May 84
7. THICKNESS OF OVERBURDEN: 5.4	17. ELEVATION TOP OF HOLE: 659.12'
8. DEPTH DRILLED INTO ROCK: 175.2	18. TOTAL CORE RECOVERY FOR BORING: 100 %
9. TOTAL DEPTH OF HOLE: 180.6	19. SIGNATURE OF INSPECTOR: Robert McVay

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
			0.0 to 0.1 - Asphalt.		A, B	* Drilling
			0.1 to 1.2 GRAVEL 0.1 to 0.7 - base gravel, coarse to fine, medium dense, damp, white, sandy and silty. 0.7 to 1.2 - base gravel - coarse to fine, moist, dark brown, very clayey, sandy.		C	0.0 to 8' - 10' auger, 8 to 120' - 11" dragbit, 120 to 180' - 4" carbon core. Slow drilling noted by driller after 130'.
	10'		1.2 to 5.4 CLAY -high plasticity, stiff, moist, dark brown to dark olive, slightly sandy.		D	*** No water level. Hole grouted up after E-log.
			5.4 to 8.0 SHALE - badly weathered to a soft/medium stiff clay, consistency, yellow brown, massive, calcareous, moist, silty.		Dragbit	Hole recored with gamma resistivity, and caliper. All core recovery was wrapped with cheese-cloth and sealed with a warmed up wax.
	20'		8.0 to 120.0 - dragbit, shale, unweathered contact not established.			Hole location: Hole is 102.7' from SP-700 at a bearing of S 38° W.
			120.0 to 180.6 SHALE - an unweathered dark gray to white, very limey, moderately hard(rock classification), massive, pyrite lenses scattered throughout, very pyritic from 140 to 150'.			Jars A. 0.1 to 0.7 B. 0.7 to 1.2 C. 1.2 to 5.4 D. 5.4 to 8.0
	30'		Chemical odor throughout. Green glauconite sand within from 158.6 to 160.5'.			Unweathered primary not established.

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT) | PROJECT | HOLE NO.

DL-121

Hole No. 6A4C-281

DRILLING LOG	DIVISION: SWD	INSTALLATION: F. Worth	SHEET 2 OF 5 SHEETS

1. PROJECT: San Pedro Creek, San Antonio, Tx.	10. SIZE AND TYPE OF BIT
2. LOCATION (Coordinates or Station)	11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
3. DRILLING AGENCY: USCE	12. MANUFACTURER'S DESIGNATION OF DRILL
4. HOLE NO. (As shown on drawing title and file number): 6A4C-281	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN — DISTURBED — UNDISTURBED
5. NAME OF DRILLER	14. TOTAL NUMBER CORE BOXES
6. DIRECTION OF HOLE: ☐ VERTICAL ☐ INCLINED ____ DEG. FROM VERT.	15. ELEVATION GROUND WATER
	16. DATE HOLE — STARTED — COMPLETED
7. THICKNESS OF OVERBURDEN	17. ELEVATION TOP OF HOLE
8. DEPTH DRILLED INTO ROCK	18. TOTAL CORE RECOVERY FOR BORING %
9. TOTAL DEPTH OF HOLE: 180.6	19. SIGNATURE OF INSPECTOR: Robert McVey

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
					Dragbit	
	50'					
	60'					
	70'					
	80'					

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT) PROJECT HOLE NO

DL-122

Hole No. 6A4C-281

DRILLING LOG	DIVISION SWD	INSTALLATION Ft Worth	SHEET 3 OF 5 SHEETS

1. PROJECT San Pedro Creek, San Antonio, Tx.	10. SIZE AND TYPE OF BIT
2. LOCATION (Coordinates or Station)	11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
3. DRILLING AGENCY USCE	12. MANUFACTURER'S DESIGNATION OF DRILL
4. HOLE NO. (As shown on drawing title and file number) 6A4C-281	13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN — DISTURBED — UNDISTURBED
5. NAME OF DRILLER Reese	14. TOTAL NUMBER CORE BOXES
6. DIRECTION OF HOLE ☐ VERTICAL ☐ INCLINED ____ DEG. FROM VERT.	15. ELEVATION GROUND WATER
	16. DATE HOLE — STARTED — COMPLETED
	17. ELEVATION TOP OF HOLE
7. THICKNESS OF OVERBURDEN	18. TOTAL CORE RECOVERY FOR BORING %
8. DEPTH DRILLED INTO ROCK	19. SIGNATURE OF INSPECTOR Robert McVey
9. TOTAL DEPTH OF HOLE 180.6	

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
					Drag-bit	
	90'					
	100'					
	110'					

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT) | PROJECT | HOLE NO.

DL-123

Hole No. 6A4C-281

DRILLING LOG	DIVISION SWD	INSTALLATION Ft Worth	SHEET 1 OF 5 SHEETS

1. PROJECT San Pedro Creek, San Antonio, Tx.	10. SIZE AND TYPE OF BIT
2. LOCATION (Coordinates or Station)	11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
3. DRILLING AGENCY USCE	12. MANUFACTURER'S DESIGNATION OF DRILL
4. HOLE NO. (As shown on drawing title and file number) 6A4C-281	13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN — DISTURBED — UNDISTURBED
5. NAME OF DRILLER Reese	14. TOTAL NUMBER CORE BOXES
6. DIRECTION OF HOLE [X] VERTICAL [ ] INCLINED ___ DEG. FROM VERT.	15. ELEVATION GROUND WATER
	16. DATE HOLE — STARTED — COMPLETED
7. THICKNESS OF OVERBURDEN	17. ELEVATION TOP OF HOLE
8. DEPTH DRILLED INTO ROCK	18. TOTAL CORE RECOVERY FOR BORING %
9. TOTAL DEPTH OF HOLE 180.6	19. SIGNATURE OF INSPECTOR Robert Maley

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
				Lost 0.0'	Box 1	
					2	
	130'				3	
				L00	4	
	140'			L19	5	
				G19'	6	
	150'			L3	7	
					8	
				G3	9	

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT) | PROJECT | HOLE NO.

DL-124

Hole No. 6A4C-281

DRILLING LOG	DIVISION SWD	INSTALLATION Ft. Worth	SHEET 5 OF 5 SHEETS

1. PROJECT San Pedro Creek, San Antonio, Tx.	10. SIZE AND TYPE OF BIT
2. LOCATION (Coordinates or Station)	11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
3. DRILLING AGENCY USCE	12. MANUFACTURER'S DESIGNATION OF DRILL
4. HOLE NO. (As shown on drawing title and file number) 6A4C-281	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN — DISTURBED — UNDISTURBED
5. NAME OF DRILLER Reese of Hilyard	14. TOTAL NUMBER CORE BOXES
6. DIRECTION OF HOLE ☐ VERTICAL ☐ INCLINED ___ DEG. FROM VERT.	15. ELEVATION GROUND WATER
7. THICKNESS OF OVERBURDEN	16. DATE HOLE — STARTED — COMPLETED
8. DEPTH DRILLED INTO ROCK	17. ELEVATION TOP OF HOLE
9. TOTAL DEPTH OF HOLE 180.6	18. TOTAL CORE RECOVERY FOR BORING %
	19. SIGNATURE OF INSPECTOR Robert McVey

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
				63 from above	9	
					10	
				100	11	
	170'					
					12	
				100	13	
	180'					

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT) PROJECT HOLE NO.

DL-125

Hole No 6A4C-282

DRILLING LOG	DIVISION SWD	INSTALLATION Ft W...	SHEET 1 of 5 SHEETS

1. PROJECT San Pedro Creek, San Antonio, Tx.	10. SIZE AND TYPE OF BIT *
2. LOCATION (Coordinates or Station)	11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
3. DRILLING AGENCY USCE	12. MANUFACTURER'S DESIGNATION OF DRILL Gardner Denver 1500
4. HOLE NO. (As shown on drawing title and file number) 6A4C-282	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN — DISTURBED 2 — UNDISTURBED 0
5. NAME OF DRILLER Reese of Hilyard drilling	14. TOTAL NUMBER CORE BOXES 13
6. DIRECTION OF HOLE [X] VERTICAL [ ] INCLINED ___ DEG. FROM VERT.	15. ELEVATION GROUND WATER ***
	16. DATE HOLE — STARTED 2 May 84 — COMPLETED 7 May 84
	17. ELEVATION TOP OF HOLE 656.0'
7. THICKNESS OF OVERBURDEN 5.0	18. TOTAL CORE RECOVERY FOR BORING 100 %
8. DEPTH DRILLED INTO ROCK 175.0	19. SIGNATURE OF INSPECTOR Robert McVey
9. TOTAL DEPTH OF HOLE 180.0	

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
			0.0 to 0.1 - Asphalt.		A	* Drilling
			0.1 to 1.0 GRAVEL - base material, fine to coarse, dense, dry, dark brown, very clayey & sandy.		B	0.0 to 1.0 - 11" dragbit 1.0 to 5.5' - 10" auger, 5.5 to 120' - 11" drag-bit. 120 to 180' - 4" carbon core. Driller called slower drilling after 145'.
			1.0 to 5.0 CLAY - high plasticity, medium stiff, moist, dark brn, very gravelly until 2', slightly gravelly and sandy from 2 to 5'.		C	*** Hole bailed after completion of drilling. Left open for future water check, E-log, and grouting.
	10'		5.0 to 45' SHALE - badly weathered to weathered, yellow brown and light gray, massive, moist, calcareous, some lime within, soft to moderately soft (rock classification), mostly plastic consistency, especially near top of section.		11" Drag-bit	Hole location: 27.3' from SP-600 at a bearing of S 82° F. Jars A. 0.1 to 1.0 B. 1.0 to 5.0 C. 5.0 to 5.5
	20		45.0 to 180.0 SHALE - an unweathered dark gray to white, very limey, moderately hard(rock classification), massive, calc, pyrite lenses scattered throughout. slightly glauconitic green sand within shale from 159.9 to 162.0'.			All core recovery was wrapped in cheesecloth and sealed with a warmed up wax and placed in core boxes. Unweathered shale @ 45'
	30'					
	40'					

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT) | PROJECT | HOLE NO.

DL-126

Hole No. 6A4C-2B2

DRILLING LOG	Division SWD	INSTALLATION Ft Worth	SHEET of 5 SHEETS

1. PROJECT San Pedro Creek, San Antonio, Tx.
2. LOCATION (Coordinates or Station)
3. DRILLING AGENCY USCE
4. HOLE NO. (As shown on drawing title and file number) 6A4C-2B2
5. NAME OF DRILLER
6. DIRECTION OF HOLE ☐ VERTICAL ☐ INCLINED ____ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN
8. DEPTH DRILLED INTO ROCK
9. TOTAL DEPTH OF HOLE 180'
10. SIZE AND TYPE OF BIT
11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
12. MANUFACTURER'S DESIGNATION OF DRILL
13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN | DISTURBED | UNDISTURBED
14. TOTAL NUMBER CORE BOXES
15. ELEVATION GROUND WATER
16. DATE HOLE | STARTED | COMPLETED
17. ELEVATION TOP OF HOLE
18. TOTAL CORE RECOVERY FOR BORING %
19. SIGNATURE OF INSPECTOR Robert McVey

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	50'				Dry Hy	
	60'					
	70'					
	80'					

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT) | PROJECT | HOLE NO.

DL-127

Hole No. 6A AC-282

DRILLING LOG	DIVISION SWD	INSTALLATION Ft Worth	SHEET of 5 SHEETS

1. PROJECT San Pedro Creek, San Antonio, Tx.	10. SIZE AND TYPE OF BIT
2. LOCATION (Coordinates or Station)	11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
3. DRILLING AGENCY	12. MANUFACTURER'S DESIGNATION OF DRILL
4. HOLE NO. (As shown on drawing title and file number) 6AAC-282	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN — DISTURBED — UNDISTURBED
5. NAME OF DRILLER	14. TOTAL NUMBER CORE BOXES
6. DIRECTION OF HOLE ☐ VERTICAL ☐ INCLINED ___ DEG. FROM VERT.	15. ELEVATION GROUND WATER
7. THICKNESS OF OVERBURDEN	16. DATE HOLE — STARTED — COMPLETED
8. DEPTH DRILLED INTO ROCK 180'	17. ELEVATION TOP OF HOLE
9. TOTAL DEPTH OF HOLE	18. TOTAL CORE RECOVERY FOR BORING %
	19. SIGNATURE OF INSPECTOR Robert McKey

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	90'					
	100'				Drag bit	
	110'					
	120'					

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT) PROJECT HOLE NO.

DL-128

Hole No. 6AAC-2R2

DRILLING LOG	DIVISION SWD	INSTALLATION Ft Wor	SHEET OF SHEETS
1. PROJECT San Pedro Creek, San Antonio		10. SIZE AND TYPE OF BIT	
2. LOCATION (Coordinates or Station)		11. DATUM FOR ELEVATION SHOWN (TBM or MSL)	
3. DRILLING AGENCY USCE		12. MANUFACTURER'S DESIGNATION OF DRILL	
4. HOLE NO. (As shown on drawing title and file number) 6AAC-2R2		13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED / UNDISTURBED	
5. NAME OF DRILLER Boone		14. TOTAL NUMBER CORE BOXES	
6. DIRECTION OF HOLE: [ ] VERTICAL [ ] INCLINED ___ DEG. FROM VERT.		15. ELEVATION GROUND WATER	
7. THICKNESS OF OVERBURDEN		16. DATE HOLE: STARTED / COMPLETED	
8. DEPTH DRILLED INTO ROCK		17. ELEVATION TOP OF HOLE	
9. TOTAL DEPTH OF HOLE		18. TOTAL CORE RECOVERY FOR BORING	
		19. SIGNATURE OF INSPECTOR Robert McGee	

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
					Box 1	
				Lost 0.2'		
					2	
	130'				3	
				Lo 1	4	
	140'				5	
				Go 1	6	
	150'				7	
				Go 1	8	
					9	
	160'					

ENG FORM 1836 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT)
MAR 71

PROJECT | HOLE NO.

DL-129

Hole No. 6ABC-2R2

DRILLING LOG	DIVISION SWD	INSTALLATION Ft Wor...	SHEET 5 OF 5 SHEETS

1. PROJECT: San Pedro Creek, San Antonio, Tx.
2. LOCATION (Coordinates or Station):
3. DRILLING AGENCY: USCE
4. HOLE NO. (As shown on drawing title and file number): 6ABC-2R2
5. NAME OF DRILLER:
6. DIRECTION OF HOLE: [ ] VERTICAL [ ] INCLINED ______ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN
8. DEPTH DRILLED INTO ROCK
9. TOTAL DEPTH OF HOLE
10. SIZE AND TYPE OF BIT
11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
12. MANUFACTURER'S DESIGNATION OF DRILL
13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED / UNDISTURBED
14. TOTAL NUMBER CORE BOXES
15. ELEVATION GROUND WATER
16. DATE HOLE: STARTED / COMPLETED
17. ELEVATION TOP OF HOLE
18. TOTAL CORE RECOVERY FOR BORING %
19. SIGNATURE OF INSPECTOR: Robert McVay

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
					9	
					10	
				Loc		
					11	
	170'					
					12	
				G		
					13	
	180'					

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT) PROJECT HOLE NO.

Hole No. 3F-283

DRILLING LOG	DIVISION SWD	INSTALLATION F-WD	SHEET 1 of 5 SHEETS
1. PROJECT SAN PEDRO TUNNEL, SAN ANTONIO, TX.		10. SIZE AND TYPE OF BIT 5 7/8" FISHTAIL BIT	
2. LOCATION (Coordinates or Station) SEE REMARKS COLUMN # 5		11. DATUM FOR ELEVATION SHOWN (TBM or MSL)	
3. DRILLING AGENCY USCE-C (HAMILTON DRILLING)		12. MANUFACTURER'S DESIGNATION OF DRILL DAMCO 1250	
4. HOLE NO. (As shown on drawing title and file number) 3F-283		13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED 0 : UNDISTURBED 0	
5. NAME OF DRILLER R. BROTHERS		14. TOTAL NUMBER CORE BOXES N/A	
6. DIRECTION OF HOLE: VERTICAL / INCLINED ___ DEG. FROM VERT.		15. ELEVATION GROUND WATER SEE REMARKS COLUMN	
7. THICKNESS OF OVERBURDEN 6.0' ±		16. DATE HOLE: STARTED 15 AUG. 84 COMPLETED 20 AUG. 84	
8. DEPTH DRILLED INTO ROCK 174.0' ±		17. ELEVATION TOP OF HOLE 646' ±	
9. TOTAL DEPTH OF HOLE 180.0'		18. TOTAL CORE RECOVERY FOR BORING N/A %	
		19. SIGNATURE OF INSPECTOR Jack R. Stokes	

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	0.0		0.0' TO 6.0' ± CLAY: 0.0'-1.8': MEDIUM-HIGH PLASTICITY; DARK BROWN; HARD; DAMP; CALCAREOUS; WITH OCCASIONAL GRAVEL 1.8'-6.0' ±: MEDIUM-HIGH PLASTICITY; GRAYISH BROWN; HARD; DRY; LIMY		10" AUGER	1. WATER LEVEL: NOTE: SMALL AMOUNT OF FREE WATER ENTERING BORING DURING AUGERING AT 22.0' ±, NOTE: BORING TO BE BAILED AFTER E-LOGGING
	6.0		6.0' ± TO 28.0' ± CLAY SHALE: HIGHLY WEATHERED; YELLOWISH BROWN WITH LIGHT GRAY; SOFT; DAMP TO MOIST AT 22.0' ±; CALCAREOUS			2. SAMPLES: NOTE: NO SAMPLES WERE RETAINED DURING DRILLING
	20				8" FLIGHT AUGER	3. DRILLING: 10" FLIGHT AUGER: 0.0' - 10.0' 8" FLIGHT AUGER: 10.0' - 38.0' NOTE: SET 6" PVC PIPE TO 38.0' & GROUTED IN PLACE & ALLOWED TO SET UP OVERNIGHT 5 7/8' FISHTAIL BIT: 38.0' - 180.0
			28.0' ± TO 180.0' T.D. SHALE (MARL): UNWEATHERED, MEDIUM-DARK GRAY (DRIES TO A LIGHT GRAY); SOFT-MODERATELY SOFT WITH OCCASIONAL HARD LIMY SEAMS; CALCAREOUS			4. NOTE: RESISTIVITY, GAMMA & CALIPER LOGS TO BE RUN IN BORING ON 24 AUG 84
	40					

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT) | PROJECT SAN PEDRO TUNNEL | HOLE NO. 3F-283

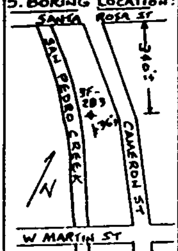
DL-131

Hole No. 3F - 283

DRILLING LOG	DIVISION	INSTALLATION	SHEET 2 OF 5 SHEETS

1. PROJECT: San Pedro Tunnel, San Antonio, Tx.	10. SIZE AND TYPE OF BIT
2. LOCATION (Coordinates or Station)	11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
3. DRILLING AGENCY	12. MANUFACTURER'S DESIGNATION OF DRILL
4. HOLE NO. (As shown on drawing title and file number): 3F-283	13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN — DISTURBED — UNDISTURBED
5. NAME OF DRILLER	14. TOTAL NUMBER CORE BOXES
6. DIRECTION OF HOLE ☐ VERTICAL ☐ INCLINED ___ DEG. FROM VERT.	15. ELEVATION GROUND WATER
	16. DATE HOLE — STARTED: 15 Aug. 84 — COMPLETED: 20 Aug. 84
7. THICKNESS OF OVERBURDEN	17. ELEVATION TOP OF HOLE
8. DEPTH DRILLED INTO ROCK	18. TOTAL CORE RECOVERY FOR BORING %
9. TOTAL DEPTH OF HOLE	19. SIGNATURE OF INSPECTOR: Jackie R. Stokes

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	60					5. BORING LOCATION:
	80					



NOTE: SKETCH NOT TO SCALE

NOTE: BORING WAS DRILLED ON CITY OF SAN ANTONIO PROPERTY WITH RIGHT OF ENTRY OBTAINED BY S.A.R.A.

ENG FORM MAR 71 1836 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT) | PROJECT: SAN PEDRO TUNNEL | HOLE NO. 3F-283

DL-132

Hole No. 3F-283

DRILLING LOG	DIVISION	INSTALLATION	SHEET 3 OF 5 SHEETS
1. PROJECT: SAN PEDRO CREEK, SAN ANTONIO, TX.		10. SIZE AND TYPE OF BIT	
2. LOCATION (Coordinates or Station)		11. DATUM FOR ELEVATION SHOWN (TBM or MSL)	
3. DRILLING AGENCY		12. MANUFACTURER'S DESIGNATION OF DRILL	
4. HOLE NO. (As shown on drawing title and file number): 3F-283		13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN	DISTURBED / UNDISTURBED
5. NAME OF DRILLER		14. TOTAL NUMBER CORE BOXES	
6. DIRECTION OF HOLE: VERTICAL / INCLINED ___ DEG. FROM VERT.		15. ELEVATION GROUND WATER	
		16. DATE HOLE	STARTED 15 AUG. 84 / COMPLETED 20 AUG. 84
7. THICKNESS OF OVERBURDEN		17. ELEVATION TOP OF HOLE	
8. DEPTH DRILLED INTO ROCK		18. TOTAL CORE RECOVERY FOR BORING	%
9. TOTAL DEPTH OF HOLE		19. SIGNATURE OF INSPECTOR: Jackie R. [signature]	

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	100				5 7/8" FISHTAIL BIT	
	120					

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT)

PROJECT: SAN PEDRO CREEK HOLE NO. 3F-283

DL-133

Hole No. 3F-283

DRILLING LOG	DIVISION	INSTALLATION	SHEET 4 OF 5 SHEETS

1. PROJECT: SAN PEDRO TUNNEL, SAN ANTONIO, TX	10. SIZE AND TYPE OF BIT
2. LOCATION (Coordinates or Station)	11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
3. DRILLING AGENCY	12. MANUFACTURER'S DESIGNATION OF DRILL
4. HOLE NO. (As shown on drawing title and file number): 3F-283	13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN — DISTURBED — UNDISTURBED
5. NAME OF DRILLER	14. TOTAL NUMBER CORE BOXES
6. DIRECTION OF HOLE: [ ] VERTICAL [ ] INCLINED ______ DEG. FROM VERT.	15. ELEVATION GROUND WATER
	16. DATE HOLE — STARTED 15 AUG 84 — COMPLETED 20 AUG 84
7. THICKNESS OF OVERBURDEN	17. ELEVATION TOP OF HOLE
8. DEPTH DRILLED INTO ROCK	18. TOTAL CORE RECOVERY FOR BORING %
9. TOTAL DEPTH OF HOLE	19. SIGNATURE OF INSPECTOR: Jackie R. Stokes

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	140					
	160					

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT)

PROJECT: SAN PEDRO TUNNEL — HOLE NO. 3F-283

DL-134

Hole No. 3F-283

DRILLING LOG	DIVISION	INSTALLATION	SHEET 5 OF 5 SHEETS

1. PROJECT: SAN PEDRO TUNNEL, SAN ANTONIO, TX.	10. SIZE AND TYPE OF BIT
2. LOCATION (Coordinates or Station)	11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
3. DRILLING AGENCY	12. MANUFACTURER'S DESIGNATION OF DRILL
4. HOLE NO. (As shown on drawing title and file number): 3F-283	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN — DISTURBED — UNDISTURBED
5. NAME OF DRILLER	14. TOTAL NUMBER CORE BOXES
6. DIRECTION OF HOLE: ☐ VERTICAL ☐ INCLINED ___ DEG. FROM VERT.	15. ELEVATION GROUND WATER
7. THICKNESS OF OVERBURDEN	16. DATE HOLE — STARTED 15 AUG 84 — COMPLETED 20 AUG 84
8. DEPTH DRILLED INTO ROCK	17. ELEVATION TOP OF HOLE
9. TOTAL DEPTH OF HOLE	18. TOTAL CORE RECOVERY FOR BORING %
	19. SIGNATURE OF INSPECTOR: Jackie R. Stroben

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	180.0		T.D. 180.0'			
	200					

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT) — PROJECT: SAN PEDRO TUNNEL — HOLE NO. 3F-283

Hole No. 3F-284

DRILLING LOG	DIVISION SWD	INSTALLATION FWD	SHEET 1 OF 5 SHEETS

1. PROJECT: SAN PEDRO TUNNEL, SAN ANTONIO, TX.	10. SIZE AND TYPE OF BIT: 5 1/2" FISHTAIL BIT
2. LOCATION (Coordinates or Station): SEE REMARKS COLUMN # 5	11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
3. DRILLING AGENCY: USCE-C (HAMILTON DRILLING)	12. MANUFACTURER'S DESIGNATION OF DRILL: DAMCO 1250
4. HOLE NO. (As shown on drawing title and file number): 3F-284	13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: DISTURBED 0, UNDISTURBED 0
5. NAME OF DRILLER: R BROTHERS	14. TOTAL NUMBER CORE BOXES: N/A
6. DIRECTION OF HOLE: ☒ VERTICAL ☐ INCLINED ___ DEG. FROM VERT.	15. ELEVATION GROUND WATER: SEE REMARKS COLUMN
	16. DATE HOLE: STARTED 20 AUG. 84, COMPLETED 23 AUG 84
7. THICKNESS OF OVERBURDEN: 6.8' ±	17. ELEVATION TOP OF HOLE: 643' ±
8. DEPTH DRILLED INTO ROCK: 173.2' ±	18. TOTAL CORE RECOVERY FOR BORING: N/A %
9. TOTAL DEPTH OF HOLE: 180.0'	19. SIGNATURE OF INSPECTOR: Jackson R. [signature]

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	0.0		0.0' TO 6.8' ± CLAY: 0.0'-5.0': MEDIUM-HIGH PLASTICITY, DARK BROWN; HARD, DRY-DAMP; CALCAREOUS, WITH GRAVEL & COBBLES. 5.0'-6.8' ±: MEDIUM PLASTICITY, LIGHT BROWN, STIFF, MOIST; VERY LIMY WITH "CALICHE"		10" AUGER	1. WATER LEVEL NOTE. FREE WATER BEGAN ENTERING BORING DURING AUGERING AT 24.0' ±. NOTE: BORING WAS BAILED TO 170' ± ON 24 AUG & LEFT OPEN FOR OBSERVATION
	6.8		6.8' ± TO 30.0' ± CLAY SHALE: HIGHLY WEATHERED, YELLOWISH BROWN WITH LIGHT GRAY, SOFT, DAMP, CALCAREOUS, MEDIUM-HIGH PLASTICITY			2 SAMPLES NOTE. NO SAMPLES WERE RETAINED DURING DRILLING
	20		24.0' ± MOIST		8" FLIGHT AUGER	3. DRILLING: 10" FLIGHT AUGER: 0.0' - 10.0. 8" FLIGHT AUGER 10.0' - 40.0'. NOTE: SET 6" PVC PIPE TO 40.0 & GROUTED IN PLACE. 5 7/8" FISHTAIL BIT: 40.0' - 180.0'
						4 NOTE: RESISTIVITY, GAMMA & CALIPER LOGS WERE RUN IN BORING ON 24 AUG 84
	30		30.0' ± TO 180.0' T.D. SHALE: (MARL): UN-WEATHERED; MEDIUM-DARK GRAY (DRIES TO A LIGHT GRAY, SOFT TO MODERATELY SOFT WITH SCATTERED HARD LIMY SEAMS, CALCAREOUS, DRY-DAMP			
	40					

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT) PROJECT: SAN PEDRO TUNNEL HOLE NO. 3F-284

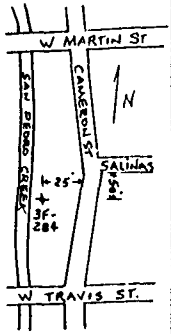
DL-136

Hole No. 3F - 284

DRILLING LOG	DIVISION	INSTALLATION	SHEET 2 OF 5 SHEETS

1. PROJECT: SAN PEDRO TUNNEL, SAN ANTONIO, TX.
2. LOCATION (Coordinates or Station)
3. DRILLING AGENCY
4. HOLE NO. (As shown on drawing title and file number): 3F - 284
5. NAME OF DRILLER
6. DIRECTION OF HOLE ☐ VERTICAL ☐ INCLINED ______ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN
8. DEPTH DRILLED INTO ROCK
9. TOTAL DEPTH OF HOLE
10. SIZE AND TYPE OF BIT
11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
12. MANUFACTURER'S DESIGNATION OF DRILL
13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN | DISTURBED | UNDISTURBED
14. TOTAL NUMBER CORE BOXES
15. ELEVATION GROUND WATER
16. DATE HOLE | STARTED 20 AUG. 84 | COMPLETED 23 AUG. 84
17. ELEVATION TOP OF HOLE
18. TOTAL CORE RECOVERY FOR BORING %
19. SIGNATURE OF INSPECTOR: [illegible]

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
						5. BORING LOCATION NOTE: BORING WAS DRILLED ON CITY OF SAN ANTONIO PROPERTY WITH RIGHT OF ENTRY OBTAINED BY SARA (SKETCH NOT TO SCALE)
	60					
	80					



ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE. (TRANSLUCENT)

PROJECT SAN PEDRO TUNNEL | HOLE NO. 3F-284

DL-137

Hole No. 3F-284

DRILLING LOG	DIVISION	INSTALLATION	SHEET 3 of 5 SHEETS

1. PROJECT: SAN PEDRO TUNNEL, SAN ANTONIO, TX.	10. SIZE AND TYPE OF BIT
2. LOCATION (Coordinates or Station)	11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
3. DRILLING AGENCY	12. MANUFACTURER'S DESIGNATION OF DRILL
4. HOLE NO. (As shown on drawing title and file number): 3F-284	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN — DISTURBED — UNDISTURBED
5. NAME OF DRILLER	14. TOTAL NUMBER CORE BOXES
	15. ELEVATION GROUND WATER
6. DIRECTION OF HOLE: ☐ VERTICAL ☐ INCLINED ____ DEG. FROM VERT.	16. DATE HOLE — STARTED: 20 AUG. 84 — COMPLETED: 23 AUG. 84
	17. ELEVATION TOP OF HOLE
7. THICKNESS OF OVERBURDEN	18. TOTAL CORE RECOVERY FOR BORING %
8. DEPTH DRILLED INTO ROCK	19. SIGNATURE OF INSPECTOR: Jackie R. [signature]
9. TOTAL DEPTH OF HOLE	

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	100				5 7/8" FISHTAIL BIT	
	120					

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT)

PROJECT: SAN PEDRO TUNNEL — HOLE NO. 3F-284

DL-138

Hole No. 3F-284

DRILLING LOG	DIVISION	INSTALLATION	SHEET 4 OF 5 SHEETS
1. PROJECT SAN PEDRO TUNNEL, SAN ANTONIO, TX		10. SIZE AND TYPE OF BIT	
2. LOCATION (Coordinates or Station)		11. DATUM FOR ELEVATION SHOWN (TBM or MSL)	
3. DRILLING AGENCY		12. MANUFACTURER'S DESIGNATION OF DRILL	
4. HOLE NO. (As shown on drawing title and file number) 3F-284		13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN	DISTURBED / UNDISTURBED
5. NAME OF DRILLER		14. TOTAL NUMBER CORE BOXES	
6. DIRECTION OF HOLE ☐ VERTICAL ☐ INCLINED ___ DEG. FROM VERT.		15. ELEVATION GROUND WATER	
		16. DATE HOLE	STARTED 20 AUG 84 / COMPLETED 23 AUG 84
7. THICKNESS OF OVERBURDEN		17. ELEVATION TOP OF HOLE	
8. DEPTH DRILLED INTO ROCK		18. TOTAL CORE RECOVERY FOR BORING	%
9. TOTAL DEPTH OF HOLE		19. SIGNATURE OF INSPECTOR Jackie R. Stokes	

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	140					
	160					

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT)

PROJECT SAN PEDRO TUNNEL

HOLE NO. 3F-284

DL-139

Hole No. 3F-284

DRILLING LOG	DIVISION	INSTALLATION	SHEET 5 OF 5 SHEETS

1. PROJECT: SAN PEDRO TUNNEL, SAN ANTONIO, TX.	10. SIZE AND TYPE OF BIT
2. LOCATION (Coordinates or Station)	11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
3. DRILLING AGENCY	12. MANUFACTURER'S DESIGNATION OF DRILL
4. HOLE NO. (As shown on drawing title and file number): 3F-284	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN — DISTURBED — UNDISTURBED
5. NAME OF DRILLER	14. TOTAL NUMBER CORE BOXES
6. DIRECTION OF HOLE: ☐ VERTICAL ☐ INCLINED ____ DEG. FROM VERT.	15. ELEVATION GROUND WATER
	16. DATE HOLE — STARTED: 20 AUG. 84 — COMPLETED: 23 AUG. 84
7. THICKNESS OF OVERBURDEN	17. ELEVATION TOP OF HOLE
8. DEPTH DRILLED INTO ROCK	18. TOTAL CORE RECOVERY FOR BORING %
9. TOTAL DEPTH OF HOLE	19. SIGNATURE OF INSPECTOR: Jackie R. Stokes

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	180.0		T.D. 180.0'			
	200					

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT)

PROJECT: SAN PEDRO TUNNEL — HOLE NO. 3F-284

DL-140

Hole No. 6A4C-285

DRILLING LOG	DIVISION SWD	INSTALLATION FWD	SHEET 1 OF 5 SHEETS

1. PROJECT: SAN PEDRO TUNNEL, SAN ANTONIO, TX.
2. LOCATION (Coordinates or Station): SEE REMARKS COLUMN # 6
3. DRILLING AGENCY: USCE-C (HAMILTON ENGR.)
4. HOLE NO. (As shown on drawing title and file number): 6A4C-285
5. NAME OF DRILLER: R. BROTHERS
6. DIRECTION OF HOLE: [X] VERTICAL [ ] INCLINED ___ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN: 17.0'±
8. DEPTH DRILLED INTO ROCK: 153.0'±
9. TOTAL DEPTH OF HOLE: 170.0'
10. SIZE AND TYPE OF BIT: 5 1/2 CARBOLOY
11. DATUM FOR ELEVATION SHOWN (TBM or MSL):
12. MANUFACTURER'S DESIGNATION OF DRILL: FAILING 1500
13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: DISTURBED 7; UNDISTURBED 0
14. TOTAL NUMBER CORE BOXES: 12
15. ELEVATION GROUND WATER: SEE REMARKS COLUMN
16. DATE HOLE: STARTED 17 MAY 84; COMPLETED 24 MAY 84
17. ELEVATION TOP OF HOLE: 645.4'±
18. TOTAL CORE RECOVERY FOR BORING: 98 %
19. SIGNATURE OF INSPECTOR: [signature]

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	0.0		0.0' TO 1" ASPHALT SURFACE		A	1. NOTE: FREE WATER LEVEL WAS ENTERING BORING DURING AUGERING AT 14.5-17.0'.
			1" TO 6 1/2" GRAVEL BASE		B	
			6 1/2" TO 7.0 CLAY: 6 1/2"-3.0: MEDIUM-HIGH PLASTICITY; DARK BROWN, HARD; DAMP; CALCAREOUS, WITH NODULES		C	2. JAR SAMPLES: A 6 1/2" - 3.0'; B: 3.0' - 4.5'; C: 4.5' - 7.0'; D: 7.0 - 12.0'; E: 12.0 - 13.6'; F: 13.6' - 14.5; G: 14.5' - 17.0'; H: 17.0' - 21.5'
			3.0'-7.0': MEDIUM PLASTICITY; BROWN DOWN TO LIGHT BROWN AT 4.5'; HARD; DAMP; VERY CALCAREOUS; WITH NODULES		D	
			7.0' TO 13.6' GRAVEL: GRADED; LIMESTONE & CHERT; MEDIUM; DAMP; LIMY, CLAYEY		E	
					F	3. NOTE: NO CARTON SAMPLES TAKEN; ALL CORE WRAPPED IN PARAFFIN AND BOXED.
	17.0		13.6' TO 14.5' CLAY: MEDIUM PLASTICITY; YELLOWISH BROWN & LIGHT GRAY; STIFF, MOIST; CALCAREOUS		G	
	20		14.5' TO 17.0'± GRAVEL: GRADED; LS & CHERT, DENSE, WET; LIMY; SLIGHTLY CLAYEY, WITH COBBLES		H	4. DRILLING: 10' FLIGHT AUGER: 0.0' - 21.5'. NOTE: SET 8" STEEL CASING TO 21.5'. 6 1/8" FISHTAIL: 21.5' - 106.0'. 5 1/2" CORE BARREL: 106.0' - 159.0'. 5 1/2" FISHTAIL: 159.0 - 170.0
			17.0'± TO 35.0'± CLAY SHALE: HIGHLY WEATHERED; YELLOWISH BROWN & LIGHT GRAY; SOFT; DAMP, CALCAREOUS, MEDIUM-HIGH PLASTICITY			5. NOTE: E-LOG, GAMMA & CALIPER LOGS WERE RUN IN BORING ON 25 MAY 84. NOTE: BORING WAS BAILED & GROUTED ON 25 MAY 84
	40		35.0'± TO 170.0' T.D. SHALE: (MARL): UNWEATHERED, DARK GRAY (DRIES TO LIGHTER GRAY), SOFT-MODERATELY SOFT DOWN TO MODERATELY			

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT) | PROJECT SAN PEDRO | HOLE NO. 6A4C-285

DL-141

Hole No. GA4C-285

DRILLING LOG | | | SHEET 2 OF 5 SHEETS

PROJECT: SAN PEDRO TUNNEL, San Antonio, Tx.

HOLE NO.: GA4C-285

DATE HOLE: STARTED 17MAY84 COMPLETED 24MAY84

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS g
			HARD - HARD Limy SEAMS; DRY - DAMP; CALCAREOUS; FOSSILIFEROUS; WITH SCATTERED PYRITE CONCENTRATIONS; BREAKS PREDOMINANTLY WITH A CONCHOIDAL FRACTURE; WITH OCCASIONAL FRACTURE AS INDICATED BELOW		6 7/8" Fishtail	6. BORING LOCATION: BORING DRILLED 105' N75°W OF T.B M. (SP-300). BORING DRILLED IN CITY PARKING LOT ON EAST SIDE OF SANTA ROSA ST.; SOUTH OF DOLOROSA ST. & NORTH OF W. NUEVA ST.
	60					
	80					

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE. (TRANSLUCENT)

PROJECT: SAN PEDRO TUNNEL

HOLE NO.: GA4C-285

Hole No. 6AAC-285

DRILLING LOG — Sheet 3 of 5 sheets

Project: SAN PEDRO TUNNEL, SAN ANTONIO TX.

Hole No.: 6AAC-285

Date hole: Started 17 MAY 84 — Completed 24 MAY 84

Signature of inspector: Jackie R. Stokes

Elevation	Depth	Legend	Classification of materials	% Core recovery	Box or sample no.	Remarks
	100					
			106.0'-107.0': HARD; VERY LIMY	106.0		
			106.0'-108.0': BROKEN (MECHANICAL) DUE TO REMOVAL FROM CORE BARREL	L:1.0'	1	
			109.0'-112.2': HARD; VERY LIMY	109.0		
				L:0.0'		
				114.0	2	
			114.3'-115.2': SOFT; 'GUMMY'			
			115.2'-119.0': HARD, LIMY	L:0.0		
			117.0': PYRITE		3	
			119.0': 45° OPEN FRACTURE	119.0		
	120					

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT)

Project: SAN PEDRO TUNNEL — Hole No. 6AAC-285

DL-143

Hole No. 6A4C-285

DRILLING LOG | SHEET 4 of 5 SHEETS

PROJECT: SAN PEDRO TUNNEL, San Antonio, Tx

HOLE NO.: 6A4C-285

DATE HOLE: STARTED 17 MAY 84 COMPLETED 24 MAY 84

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS
			121.0'-132.0': VERY HARD; VERY LIMY 122.0': PYRITE 122.7': 45° OPEN FRACTURE	L:0.0 124.5	4	
				L:0.3 129.0	5	
				L:0.7 134.0	6	
				L:0.0 137.0	7	
	140		138.6': PYRITE 139.8': " 140.5': 45° OPEN FRACTURE	L:0.0 141.5	8	
			141.0'-142.0': SLIGHTLY SOFTER 142.6': PYRITE 144.8': THIN FOSSIL 146.0-170.0: HARD, VERY LIMY 146.5: PYRITE	6:1.0 146.0	9	
			148.2': " 150.0: "	L:0.0 151.0	10	
			152.8': 45° "SLICK" (OPENED DURING HANDLING) 155.0: PYRITE	L:0.0 156.0	11	
				L:0.0 158.0 L:0.0 159.0	12	
	160				↑	

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT)

PROJECT: SAN PEDRO TUNNEL | HOLE NO. 6A4C-285

DL-144

Hole No. 6A4C-285

DRILLING LOG

Sheet 5 of 5 sheets

SAN PEDRO TUNNEL San Antonio, Tx.

6A4C-285

17 MAY 84 24 MAY 84

5 7/8" Fishtail

170.0

T.D. 170.0'

180

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT)

PROJECT SAN PEDRO TUNNEL

HOLE NO. 6A4C-285

DL-145

DRILLING LOG | SWD | FWD | Hole No. 6A4C-286 | Sheet 1 of 5 sheets

SAN PEDRO TUNNEL, San Antonio, TX.

SEE REMARKS COLUMN # 6

LESSEE (HARRINGTON DRILLING)

6A4C-286

R. BROTHERS

20.5' ±

159.5' ±

180.0'

5 1/2" CARBOLOY

DAMCO 1250

0 : 0

22.

SEE REMARKS COLUMN

6 SEPT 84 | 10 SEPT 84

645' ±

99

Elevation	Depth	Legend	Classification of materials	% Core recovery	Box or sample no.	Remarks
	0.0		0.0' TO 0.1' ASPHALT SURFACE 0.1' TO 0.5' GRAVEL BASE 0.5' TO 4.0' CLAY FILL: 0.5-3.0': MEDIUM-HIGH PLASTICITY; BLACK; HARD; DAMP; GRAVELLY; CALCAREOUS; WITH BRICK FRAGMENTS 3.0'-4.0': MEDIUM PLASTICITY; LIGHT BROWN-TAN; HARD; DAMP; VERY LIMY 4.0' TO 18.5' CLAY: 4.0'-10.0': MEDIUM-HIGH PLASTICITY; DARK BROWN; STIFF-VERY STIFF; SLIGHTLY MOIST, CALCAREOUS; WITH SCATTERED GRAVEL 10.0'-12.5': MEDIUM-HIGH PLASTICITY; DARK BROWN; MEDIUM-STIFF, VERY MOIST; SILTY, CALCAREOUS 12.5'-16.0': MEDIUM-HIGH PLASTICITY; LIGHT BROWN-TAN; GRAY FROM FROM 14.0'; MEDIUM-STIFF; VERY MOIST; VERY LIMY; WITH SCATTERED GRAVEL FROM 14.0' 16.0-18.5': MEDIUM-HIGH PLASTICITY; TAN & GRAY; VERY STIFF; DAMP-SLIGHTLY MOIST; LIMY WITH NODULES 18.5' TO 20.5' ± GRAVEL: MEDIUM, L.S & CHERT; LIGHT BROWN, WET, LIMY; VERY CLAYEY (MUCKY)		10" FLIGHT AUGER	1. WATER LEVEL: NOTE: FREE WATER BEGAN ENTERING DURING AUGERING AT 14.0'; NOTE BORING BAILED TO NEAR T.D. ON 11 SEPT. 84 2. CARTON SAMPLES: C-1: 56.2'-57.2'; 2: 61.5'-62.5'; 3: 67.2'-68.2'; 4: 71.9'-72.9'; 5: 77.5'-78.5'; 6: 83.1'-84.1'; 7: 88.3'-89.3'; 8: 94.8'-95.8'; 9: 100.6'-101.6'; 10: 105.9'-106.9'; 11: 111.6'-112.6'; 12: 116.8'-117.8; 13: 122.6'-123.6'; 14: 128.9'-129.9; 15: 134.8'-135.8; 16: 140.6'-141.6'; 17: 146.7-147.7'; 18: 151.9'-152.9'; 19: 158.2'-159.2; 20: 162.7'-163.7; 21: 168.9'-169.9; 22: 174.7'-175.7'
	20 20.5		20.5' ± TO 42.0' ± CLAY SHALE: HIGHLY WEATHERED; YELLOWISH BROWN & LIGHT GRAY, SOFT, DAMP, CALCAREOUS, MEDIUM-HIGH PLASTICITY		8" FLIGHT AUGER	3. NOTE: CORE WAS PHOTOGRAPHED & BOXED 4. NOTE: RESISTIVITY, GAMMA & CALIPER LOGS WERE RUN IN BORING AFTER DRILLING
	40					

ENG FORM 1836 PREVIOUS EDITIONS ARE OBSOLETE | PROJECT SAN PEDRO TUNNEL | HOLE NO. 6A4C-286

Hole No. 6A4C-286

DRILLING LOG

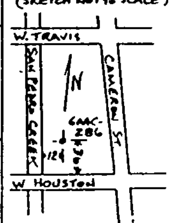
Sheet 2 of 5 sheets

1. PROJECT: SAN PEDRO TUNNEL, SAN ANTONIO, TX.

4. HOLE NO.: 6A4C-286

16. DATE HOLE: Started 6 SEPT. 84; Completed 10 SEPT. 84

19. SIGNATURE OF INSPECTOR: Joshua R. [illegible]

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS
			42.0'± TO 180.0' T.D. SHALE (MARL): UNWEATHERED; DARK GRAY (DRIES TO A LIGHT GRAY; MODERATELY SOFT TO HARD; DRY-DAMP; CALCAREOUS, WITH HARD LIMY SEAMS, FOSSILIFEROUS; WITH SCATTERED PYRITE NUGGETS; BREAKS PREDOMINANTLY WITH A CONCHOIDAL FRACTURE; W/NO FRACTURES	51.5		5. DRILLING: 10" FLIGHT AUGER: 0.0' - 21.0'. NOTE: SET 8" STEEL CASING TO 21.0'. 8" FLIGHT AUGER: 21.0' - 51.0'. NOTE: SET 6" PVC PIPE TO 51.0; GROUTED IN PLACE & PULLED 8" STEEL PIPE. 5½" FISHTAIL BIT 51.0' - 51.5. 5½" CORE BARREL 51.5' - 180.0'
		1	42.0'± - 53.5: SOFT-MODERATELY SOFT. 53.5' - 55.0: HARD; VERY LIMY. 55.0' - 58.5': SOFT-MODERATELY SOFT. 57.2: LARGE FOSSIL. 57.8: " "	1:1.0	1	6. BORING LOCATION: (SKETCH NOT TO SCALE)
	60		58.5 - 63.0': HARD, VERY LIMY	61.5	2	
		2	63.0 - 65.0' MODERATELY SOFT			
		3	65.0' - 77.5': SOFT-MODERATELY SOFT	6.0 4	3	NOTE: BORING DRILLED ON CITY PROPERTY WITH RIGHT OF ENTRY OBTAINED BY S A R A
		4		70.5	4	
		5	77.5' - 81.6': HARD, VERY LIMY	1:0 2	5	
	80			79.5		

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT)

PROJECT: SAN PEDRO TUNNEL — HOLE NO. 6A4C-286

DL-147

Hole No. 6A4C-286

DRILLING LOG	DIVISION	INSTALLATION	SHEET 3 OF 5 SHEETS

1. PROJECT SAN PEDRO TUNNEL, SAN ANTONIO, TX.	10. SIZE AND TYPE OF BIT
2. LOCATION (Coordinates or Station)	11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
3. DRILLING AGENCY	12. MANUFACTURER'S DESIGNATION OF DRILL
4. HOLE NO. (As shown on drawing title and file number) 6A4C-286	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN — DISTURBED — UNDISTURBED
5. NAME OF DRILLER	14. TOTAL NUMBER CORE BOXES
6. DIRECTION OF HOLE ☐ VERTICAL ☐ INCLINED ____ DEG. FROM VERT.	15. ELEVATION GROUND WATER
	16. DATE HOLE — STARTED 6 SEPT. 84 — COMPLETED 10 SEPT. 84
7. THICKNESS OF OVERBURDEN	17. ELEVATION TOP OF HOLE
8. DEPTH DRILLED INTO ROCK	18. TOTAL CORE RECOVERY FOR BORING %
9. TOTAL DEPTH OF HOLE	19. SIGNATURE OF INSPECTOR

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
		6	81.6'-98.2': MODERATELY SOFT	5:06	6	
		7		88.5	7	
		8		L:07	8	
	100	9	98.2'-110.0: HARD, VERY LIMY 100.7': PYRITE	98.5	9	
		10		L:0.7 107.5	10	
		11	110.0'-133.0': MODERATELY HARD	6:01 115.0	11	
	120	12		6:11	12	

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT) — PROJECT SAN PEDRO TUNNEL — HOLE NO. 6A4C-286

Hole No. 6A4C-286

DRILLING LOG | Division | Installation | Sheet 4 of 5 sheets

1. Project: SAN PEDRO TUNNEL, SAN ANTONIO, TX.

4. Hole No.: 6A4C-286

16. Date hole: Started 6 SEPT. 84 — Completed 10 SEPT 84

19. Signature of inspector: [signature]

Elevation	Depth	Legend	Classification of materials	% Core recovery	Box or sample no.	Remarks
		13	122.3': PYRITE	124.0	13	
		14	126.2': PYRITE	L:00	14	
		15	132.6'-133.8': MECHANICAL BREAK; 133.0'-136.0': HARD, VERY LIMY; 134.3': PYRITE; 136.0'-141.0': MODERATELY HARD; LIMY; 137.3'-137.5': BLACK PYRITIC BAND	133.0 / L'0.0	15 / 16	
	140	16	141.0': PYRITE; 141.0-146.0': HARD, VERY LIMY; 141.6'-142.2': MECHANICAL BREAK; 142.6': PYRITE; 145.2': "; 146.0'-162.0': MODERATELY HARD; LIMY; 146.4': PYRITE	142.0 / L:02	17	
		17, 18	149.3': PYRITE; 150.0': "; 150.7': "	151.5	18	NOTE CORE WAS REMOVED FROM 151.5' TO 154.5 & GIVEN TO SARA
	160	19	155.1': PYRITE; 156.6': "; 159.7': "	5:06	19	

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT) | PROJECT: SAN PEDRO TUNNEL | HOLE NO. 6A4C-286

DL-149

Hole No. 6A4C-286

DRILLING LOG	DIVISION	INSTALLATION	SHEET 5 of 5 SHEETS
1. PROJECT San Pedro Tunnel, San Antonio, Tx.		10. SIZE AND TYPE OF BIT	
2. LOCATION (Coordinates or Station)		11. DATUM FOR ELEVATION SHOWN (TBM or MSL)	
3. DRILLING AGENCY		12. MANUFACTURER'S DESIGNATION OF DRILL	
4. HOLE NO. (As shown on drawing title and file number) 6A4C-286		13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN — DISTURBED / UNDISTURBED	
5. NAME OF DRILLER		14. TOTAL NUMBER CORE BOXES	
6. DIRECTION OF HOLE ☐ VERTICAL ☐ INCLINED ___ DEG. FROM VERT.		15. ELEVATION GROUND WATER	
7. THICKNESS OF OVERBURDEN		16. DATE HOLE — STARTED 6 Sept. 84 — COMPLETED 10 Sept. 84	
8. DEPTH DRILLED INTO ROCK		17. ELEVATION TOP OF HOLE	
9. TOTAL DEPTH OF HOLE		18. TOTAL CORE RECOVERY FOR BORING %	
		19. SIGNATURE OF INSPECTOR Jackie R. [signature]	

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
			160.6': Pyrite	160.5		
			162.0'-168.0': Hard; very limy			
		20	162.9': Pyrite		20	
			163.8'±-166.0': trace of green-sand (serpentine?)	L:06		
			166.3': Pyrite			
			168.0'-180.0: Mod-erately hard, limy			
		21			21	
				170.5		
			171.4: Pyrite			
			173.0': "			
			173.8' "			
		22		L:10	22	
	180.0		T.D 180.0'	180.0		
	200					

ENG FORM MAR 71 1836 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT) — PROJECT San Pedro Tunnel — HOLE NO. 6A4C-286

Hole No CDC-287A

DRILLING LOG | DIVISION: SWD | INSTALLATION: FWD | SHEET 1 OF 1 SHEETS

1. PROJECT: SAN PEDRO TUNNEL, SAN ANTONIO, TX	10. SIZE AND TYPE OF BIT: 6 CARBOLOY
2. LOCATION (Coordinates or Station): SEE LAYOUT	11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
3. DRILLING AGENCY: USCE-C	12. MANUFACTURER'S DESIGNATION OF DRILL: FAILING 1500
4. HOLE NO. (As shown on drawing title and file number): CDC-287A	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED 5, UNDISTURBED 2
5. NAME OF DRILLER: T. SUITS	14. TOTAL NUMBER CORE BOXES: SEE REMARKS COLUMN
6. DIRECTION OF HOLE: ☒ VERTICAL ☐ INCLINED ___ DEG. FROM VERT.	15. ELEVATION GROUND WATER: SEE REMARKS COLUMN
	16. DATE HOLE: STARTED 27 FEB 84, COMPLETED 28 FEB 84
7. THICKNESS OF OVERBURDEN: 21.0'±	17. ELEVATION TOP OF HOLE: 642'±
8. DEPTH DRILLED INTO ROCK: 4.0'±	18. TOTAL CORE RECOVERY FOR BORING: N/A
9. TOTAL DEPTH OF HOLE: 25.'	19. SIGNATURE OF INSPECTOR: [signature]

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	0.0		0.0 TO 10.0'± CLAY FILL: 0.0'-3.5' MEDIUM-HIGH PLASTICITY, DARK BROWN, HARD, DRY-DAMP CALCAREOUS, VERY GRAVELLY, WITH LARGE CONCRETE FRAGMENTS. 3.5-4.5' MEDIUM-HIGH PLASTICITY, DARK BROWN, STIFF-VERY STIFF, DAMP-SLIGHTLY MOIST, CALCAREOUS, WITH SCATTERED GRAVEL. 4.5'-10.0'± MEDIUM PLASTICITY, LIGHT BROWN-TAN, HARD, DAMP, VERY LIMY, WITH SCATTERED SMALL GRAVEL TO VERY GRAVELLY FROM 8.0'-10.0'±		A; B; C; DB 1 (1.50); DB 2 (1.00); LOST SAMPLE; NO SAMPLE; D	1 NOTE FREE WATER ENTERING BORING DURING DRILLING AT 14.0'±, WATER CASED OFF WITH 8" PVC PIPE & GROUTED IN PLACE. 2 JAR SAMPLES A 0.0'-3.5; B 3.5'-4.5; C 4.5'-6.0; D 14.0-14.8; E 14.8-21.0; F 21.0-25'. NOTE COULD NOT OBTAIN REPRESENTATIVE SAMPLE FROM 10.0-14.0 DUE TO DRILL WATER & DRILL MUD
			10.0± TO 11.0 CLAY: MEDIUM-HIGH PLASTICITY, DARK BROWN, VERY STIFF, DAMP, CALCAREOUS, WITH OCCASIONAL GRAVEL		E	3 DENISON SAMPLES DB 1 6.0-8.0; 2 8.0'-10.0. NOTE LOST SAMPLE FROM 10.0'-12.0 DUE TO GRAVEL
	20		11.0 TO 14.0 GRAVEL: MEDIUM-LARGE, LIMESTONE & CHERT, MEDIUM, MOIST, LIMY, VERY CLAYEY, WITH SCATTERED COBBLES			
	21.0		14.0 TO 14.8' CLAY: MEDIUM-HIGH PLASTICITY, GRAY WITH BROWN, STIFF, MOIST, CALCAREOUS, WITH BLACK CARBON STAINS & ORGANIC MATTER		F	4 DRILLING 10 FLIGHT AUGER 0.0-6.0. NOTE: SET 8" STEEL CASING TO 6.0. 6" DENISON BARREL 6.0-12.0. 10 FLIGHT AUGER 12.0-25.0. NOTE: PULLED STEEL CASING & SET 8" PVC CASING TO 25.0 & GROUTED
	25.0		14.8 TO 21.0± GRAVEL: MEDIUM-LARGE, LIMESTONE & CHERT, MEDIUM-DENSE, WET, MODERATELY CLAYEY, LIMY			
			21.0± TO 25.0' CLAY SHALE: HIGHLY WEATHERED, YELLOWISH BROWN & LIGHT GRAY, SOFT, DAMP, CALCAREOUS, MEDIUM-HIGH PLASTICITY			5 NOTE: BORING TO BE DEEPENED LATER WITH 6 CORE BARREL
	40					

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT) | PROJECT: SAN PEDRO TUNNEL | HOLE NO. CDC-287A

DL-151

Hole No. 6DC-287

DRILLING LOG	DIVISION: SWD	INSTALLATION: Ft Worth	SHEET 1 of 5 SHEETS

1. PROJECT: San Pedro Creek, San Antonio, Tx.
2. LOCATION (Coordinates or Station):
3. DRILLING AGENCY: U.CF
4. HOLE NO. (As shown on drawing title and file number): 6DC-287
5. NAME OF DRILLER: Reese of Hilyard drilling.
6. DIRECTION OF HOLE: [X] VERTICAL [ ] INCLINED ____ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN: see **
8. DEPTH DRILLED INTO ROCK: 150'
9. TOTAL DEPTH OF HOLE: 180'
10. SIZE AND TYPE OF BIT: *
11. DATUM FOR ELEVATION SHOWN (TBM or MSL):
12. MANUFACTURER'S DESIGNATION OF DRILL: Gardner Denver 1500
13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: DISTURBED 0 UNDISTURBED 0
14. TOTAL NUMBER CORE BOXES: 33
15. ELEVATION GROUND WATER: ***
16. DATE HOLE: STARTED 10 April 84 COMPLETED 18 April 84
17. ELEVATION TOP OF HOLE: 639.5'
18. TOTAL CORE RECOVERY FOR BORING: 100 %
19. SIGNATURE OF INSPECTOR: Robert McVey

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
			25.0 to 37.2 SHALE - weathered yellowish brown and light gray, massive, calc, soft(rock classification), some very soft plastic seams scattered from 25 to 32.9'. 37.2 to 180.0 SHALE - an unweathered dark gray and white, limey to very limey, calc, massive, mostly moderately soft to moderately hard(rock classification), a few scattered and thin(less than 0.1' thick) hard cemented seams, silty, chemical odor after 50', pyrite scattered throughout, gets very limey after 120'. No apparent dip or fractures.			* Drilling 0.0 to 25' -ream out pvc with 7 7/8' rockbit, grout from 21.5 to 25' 25 to 180' - 6" core, carbon bit. ** This hole started by government drill crew to 25' and then cased and grouted. Jack Stokes was geologist. *** Hole to be bailed after E-log. None immediately available. Hole to be bailed at a later time Hole location: Core hole is 27.5' and N22°E from SP-100. All core recovery was wrapped in cheesecloth and sealed in heated wax. Unweathered rock @ 37.2
	10					
	20					
				Lost 00	Box 1	
	30			100	2	
				100	3	
	40					

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT) | PROJECT | HOLE NO.

DL-152

Hole No.

DRILLING LOG	DIVISION	INSTALLATION	SHEET of 5 SHEETS
		Ft Worth	

1. PROJECT: San Pedro Creek, San Antonio, Tx.
2. LOCATION (Coordinates or Station)
3. DRILLING AGENCY: USCE
4. HOLE NO. (As shown on drawing title and file number): 61X-287
5. NAME OF DRILLER: Reese of Hilyard
6. DIRECTION OF HOLE: ☐ VERTICAL ☐ INCLINED ______ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN
8. DEPTH DRILLED INTO ROCK
9. TOTAL DEPTH OF HOLE: 150'
10. SIZE AND TYPE OF BIT
11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
12. MANUFACTURER'S DESIGNATION OF DRILL
13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED / UNDISTURBED
14. TOTAL NUMBER CORE BOXES: 33
15. ELEVATION GROUND WATER
16. DATE HOLE: STARTED / COMPLETED
17. ELEVATION TOP OF HOLE
18. TOTAL CORE RECOVERY FOR BORING %
19. SIGNATURE OF INSPECTOR: Robert McClary

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	40'			100	4	
				100	5	
	50'			100	6	
				100	7	
	60			100	8	
				100	9	
	70				10	
				100	11	
				103'	12	
	80					

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT) | PROJECT | HOLE NO.

DL-153

DRILLING LOG	SHEET of 5 SHEETS
PROJECT San Pedro Creek, San Antonio, Tx.	
LOCATION	
DRILLING AGENCY	
HOLE NO.	600-287
NAME OF DRILLER Reese, Filyard	
DIRECTION OF HOLE ☐ VERTICAL ☐ INCLINED	
THICKNESS OF OVERBURDEN	
DEPTH DRILLED INTO ROCK	
TOTAL DEPTH OF HOLE	180'

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS
					12	
				Loo	13	
				Loo	14	
	90					
				6an 03	15	
				Loo	16	
	100					
				Loo	17	
				Loo	18	
	110					
				102	19	
				10r	20	
	120				21	

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT) PROJECT HOLE NO.

DL-154

Hole No. [illegible]

DRILLING LOG	SWD	Ft Worth	Sheet 2 of 5 sheets

1. PROJECT: San Pedro Creek, San Antonio, Tx.
2. LOCATION (Coordinates or Station)
3. DRILLING AGENCY: [illegible]
4. HOLE NO.: 6AC-297
5. NAME OF DRILLER: Bureau of Wilmard drilling
6. DIRECTION OF HOLE: ☐ VERTICAL ☐ INCLINED ____ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN
8. DEPTH DRILLED INTO ROCK
9. TOTAL DEPTH OF HOLE: 180'

SIGNATURE OF INSPECTOR: [illegible signature]

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS g
				100	21	
					22	
				603		
	130'				23	
				100		
					24	
				601		
	140'				25	
				100	26	
				105	27	
	150'					
				604	28	
				601	29	
	160'					

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT) | PROJECT | HOLE NO.

DL-155

Hole No. 6PC-297

DRILLING LOG		Ft Worth	SHEET OF 5 SHEETS
PROJECT: San Pedro Creek, San Antonio, Tx.			
HOLE NO.: 6PC-297			
TOTAL DEPTH OF HOLE: 180'			
SIGNATURE OF INSPECTOR: Robert McKay			

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS g
				OS Cimage	29	
				Lo3'	30	
	170			Go1'	31	
				Go1	32	
				Loo	33	
	180'					

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT)

PROJECT | HOLE NO.

Hole No. 3F-295

DRILLING LOG — DIVISION: SWD	INSTALLATION: FWD — SHEET 1 OF 4 SHEETS
PROJECT: SAN PEDRO TUNNEL, SAN ANTONIO, TX	SIZE AND TYPE OF BIT: 5 7/8" FISHTAIL
LOCATION: SEE REMARKS COLUMN # 5	
DRILLING AGENCY: USCE-C (HAMILTON DRILLING)	MANUFACTURER'S DESIGNATION OF DRILL: FAMCO 1250
HOLE NO.: 3F 295	TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: 0 — 0
NAME OF DRILLER: R. BROTHERS	TOTAL NUMBER CORE BOXES: N/A
DIRECTION OF HOLE: VERTICAL	ELEVATION GROUND WATER: SEE REMARKS COL. 1
	DATE HOLE: STARTED 31 AUG 84 — COMPLETED 5 SEPT 84
THICKNESS OF OVERBURDEN: 13.0'±	ELEVATION TOP OF HOLE: 643'±
DEPTH DRILLED INTO ROCK: 162.0'±	TOTAL CORE RECOVERY FOR BORING: N/A
TOTAL DEPTH OF HOLE: 180.0'	SIGNATURE OF INSPECTOR: [signature]

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS
	0.0		0.0' To 0.1' ASPHALT SURFACE 0.1' To 0.5' GRAVEL BASE 0.5' To 16.0' CLAY: 0.5'-4.0': MEDIUM-HIGH PLASTICITY, DARK BROWN; HARD; DAMP; CALCAREOUS, GRAVELLY 4.0'-11.0': MEDIUM-HIGH PLASTICITY, DARK BROWN, HARD, DAMP; CALCAREOUS 11.0'-16.0': MEDIUM PLASTICITY, LIGHT GREENISH GRAY; MEDIUM; VERY MOIST TO WET AT 13.0'±, CALCAREOUS 16.0' To 18.0'± GRAVEL: MEDIUM-LARGE, CHERTY; LIGHT BROWN, VERY LIMY; MEDIUM; SATURATED; VERY CLAYEY		10" FLIGHT AUGER	1. WATER LEVEL: NOTE: FREE WATER ENTERING BORING DURING AUGERING AT 13.0'± NOTE: BORING WAS BAILED TO 94.0' ON 6 SEPT 84; NOTE: COULD NOT BAIL DEEPER DUE TO A RESTRICTION IN BORING FROM SHALE CUTTINGS 2. SAMPLES: NOTE: NO SAMPLES WERE RETAINED FROM DRILLING
	18.0 20		18.0'± To 34.0' CLAY SHALE: HIGHLY WEATHERED; YELLOWISH BROWN & LIGHT GRAY, SOFT; DAMP, CALCAREOUS, MEDIUM-HIGH PLASTICITY 34.0'± To 44.0' SHALE (MARL): UNWEATHERED, DARK GRAY (DRIES TO A LIGHTER GRAY), SOFT TO MODERATELY SOFT WITH SCATTERED HARD LIMY SEAMS, CALCAREOUS		8" FLIGHT AUGER	3. DRILLING 10" FLIGHT AUGER: 0.0' - 19.0' NOTE: SET 8" STEEL CASING TO 19.0 8" FLIGHT AUGER: 19.0' - 44.0 NOTE: SET 6" PVC PIPE TO 44.0, GROUTED IN PLACE & PULLED 8" CASING 5 7/8" FISHTAIL BIT 44.0 - 180.0' 4. NOTE: RESISTIVITY, GAMMA & CALIPER LOGS WERE RUN IN BORING AFTER DRILLING

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT) — PROJECT: SAN PEDRO TUNNEL — HOLE NO. 3F-295

Hole No. 3F-295

DRILLING LOG

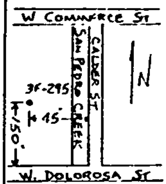
SHEET 2 OF 5 SHEETS

PROJECT: SAN PEDRO TUNNEL, SAN ANTONIO, TX.

HOLE NO.: 3F-295

DATE HOLE: STARTED 13 AUG 84, COMPLETED 5 SEPT. 84

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS
			44.0' TO 180.0' T.D. SHALE (MARL) (FISH-TAILED)			5. BORING LOCATION: NOTE: BORING DRILLED ON CITY PROPERTY WITH RIGHT OF ENTRY OBTAINED BY SARA (SKETCH NOT TO SCALE)
	60					
	80					



ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT)

PROJECT: SAN PEDRO TUNNEL — HOLE NO. 3F-295

DL-182

Hole No. 3F-295

DRILLING LOG	DIVISION	INSTALLATION	SHEET 3 OF 5 SHEETS

1. PROJECT: SAN PEDRO TUNNEL, SAN ANTONIO, TX.
2. LOCATION (Coordinates or Station)
3. DRILLING AGENCY
4. HOLE NO. (As shown on drawing title and file number): 3F-295
5. NAME OF DRILLER
6. DIRECTION OF HOLE: ☐ VERTICAL ☐ INCLINED ______ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN
8. DEPTH DRILLED INTO ROCK
9. TOTAL DEPTH OF HOLE
10. SIZE AND TYPE OF BIT
11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
12. MANUFACTURER'S DESIGNATION OF DRILL
13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: DISTURBED / UNDISTURBED
14. TOTAL NUMBER CORE BOXES
15. ELEVATION GROUND WATER
16. DATE HOLE: STARTED 31 AUG. 84 COMPLETED 5 SEPT 84
17. ELEVATION TOP OF HOLE
18. TOTAL CORE RECOVERY FOR BORING %
19. SIGNATURE OF INSPECTOR: [signature]

ELEVATION (a)	DEPTH (b)	LEGEND (c)	CLASSIFICATION OF MATERIALS (Description) (d)	% CORE RECOVERY (e)	BOX OR SAMPLE NO. (f)	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) (g)
	100				5 7/8" FISHTAIL BIT	
	120					

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT)

PROJECT: SAN PEDRO TUNNEL HOLE NO. 3F-295

DL-183

Hole No. 3F 295

DRILLING LOG	DIVISION	INSTALLATION	SHEET 4 of 5 SHEETS

1. PROJECT: SAN PEDRO TUNNEL, SAN ANTONIO, TX
2. LOCATION (Coordinates or Station)
3. DRILLING AGENCY
4. HOLE NO. (As shown on drawing title and file number): 3F-295
5. NAME OF DRILLER
6. DIRECTION OF HOLE: ☐ VERTICAL ☐ INCLINED ______ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN
8. DEPTH DRILLED INTO ROCK
9. TOTAL DEPTH OF HOLE
10. SIZE AND TYPE OF BIT
11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
12. MANUFACTURER'S DESIGNATION OF DRILL
13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED | UNDISTURBED
14. TOTAL NUMBER CORE BOXES
15. ELEVATION GROUND WATER
16. DATE HOLE: STARTED 31 AUG 84 | COMPLETED 5 SEPT 84
17. ELEVATION TOP OF HOLE
18. TOTAL CORE RECOVERY FOR BORING %
19. SIGNATURE OF INSPECTOR: Jackie K. Stokes

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	140					
	160					

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT)

PROJECT: SAN PEDRO TUNNEL | HOLE NO. 3F-295

DL-184

Hole No. 3F-295

DRILLING LOG

DIVISION	INSTALLATION
	SHEET 5 of 5 SHEETS
1. PROJECT: SAN PEDRO TUNNEL, SAN ANTONIO, TX	10. SIZE AND TYPE OF BIT
2. LOCATION (Coordinates or Station)	11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
3. DRILLING AGENCY	12. MANUFACTURER'S DESIGNATION OF DRILL
4. HOLE NO. (As shown on drawing title and file number): 3F-295	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN — DISTURBED — UNDISTURBED
5. NAME OF DRILLER	14. TOTAL NUMBER CORE BOXES
6. DIRECTION OF HOLE: VERTICAL / INCLINED ___ DEG. FROM VERT.	15. ELEVATION GROUND WATER
7. THICKNESS OF OVERBURDEN	16. DATE HOLE — STARTED: 31 AUG 84 — COMPLETED: 5 SEPT 84
8. DEPTH DRILLED INTO ROCK	17. ELEVATION TOP OF HOLE
9. TOTAL DEPTH OF HOLE	18. TOTAL CORE RECOVERY FOR BORING %
	19. SIGNATURE OF INSPECTOR: Jackson K. Stokes

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	180.0		T.D. 180.0'			
	200					

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT)

PROJECT: SAN PEDRO TUNNEL — HOLE NO. 3F-295

DL-185

Hole No. 3F-296

DRILLING LOG	DIVISION SWD	INSTALLATION FWD	SHEET 1 OF 5 SHEETS
1. PROJECT: SAN PEDRO TUNNEL, SAN ANTONIO, TX.		10. SIZE AND TYPE OF BIT: 5 7/8" FISHTAIL BIT	
2. LOCATION (Coordinates or Station): SEE REMARKS COLUMN #5		11. DATUM FOR ELEVATION SHOWN (TBM or MSL)	
3. DRILLING AGENCY: USCE-C (HAMILTON BILLING)		12. MANUFACTURER'S DESIGNATION OF DRILL: DAMCO 1250	
4. HOLE NO. (As shown on drawing title and file number): 3F 296		13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: DISTURBED 0	UNDISTURBED 0
5. NAME OF DRILLER: R. BROTHERS		14. TOTAL NUMBER CORE BOXES: N/A	
6. DIRECTION OF HOLE: ■ VERTICAL ☐ INCLINED ___ DEG. FROM VERT.		15. ELEVATION GROUND WATER: SEE REMARKS COLUMN	
		16. DATE HOLE: STARTED 27 AUG. 84	COMPLETED 29 AUG. 84
7. THICKNESS OF OVERBURDEN: 20.8' ±		17. ELEVATION TOP OF HOLE: 642' ±	
8. DEPTH DRILLED INTO ROCK: 159.2' ±		18. TOTAL CORE RECOVERY FOR BORING: N/A	
9. TOTAL DEPTH OF HOLE: 180.0'		19. SIGNATURE OF INSPECTOR: Jackie R. [signature]	

ELEVATION (a)	DEPTH (b)	LEGEND (c)	CLASSIFICATION OF MATERIALS (Description) (d)	% CORE RECOVERY (e)	BOX OR SAMPLE NO. (f)	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) (g)
	0.0		0.0' TO 0.1' ASPHALT SURFACE 0.1' TO 1.5' GRAVEL BASE 1.5' TO 11.5' ± CLAY FILL: MEDIUM-HIGH PLASTICITY, DARK BROWN, HARD TO VERY STIFF AT 9.0'; DAMP TO SLIGHTLY MOIST AT 9.0', WITH LIME NODULES FROM 5.0'; CALCAREOUS, WITH SCATTERED BRICK FRAGMENTS		10" FLIGHT AUGER	1. WATER LEVEL: NOTE: FREE WATER BEGAN ENTERING BORING AT 16.0' ± DURING AUGERING; NOTE: BORING WAS BAILED TO 178.0' ± AFTER AUGERING 2. SAMPLES. NOTE. NO SAMPLES WERE RETAINED DURING DRILLING
			11.5' ± TO 19.5' CLAY: 11.5' ±-13.0': MEDIUM-HIGH PLASTICITY; GRAY, HARD; DAMP, CALCAREOUS 13.0'-16.0': MEDIUM-HIGH PLASTICITY; YELLOWISH BROWN WITH LIGHT GRAY; HARD TO STIFF FROM 15.0' ±; DAMP TO VERY MOIST FROM 15.0' ±; CALCAREOUS, WITH SCATTERED GRAVEL			3. DRILLING: 10" FLIGHT AUGER: 0.0' - 22.0 NOTE: SET 8" STEEL CASING TO 22.0' 8" FLIGHT AUGER 22.0' - 44.0' NOTE: SET 6" PVC PIPE TO 44.0', GROUTED IN PLACE & PULLED 8" STEEL CASING 5 7/8" FISHTAIL BIT: 44.0 - 180.0
	20		16.0'-19.5': MEDIUM PLASTICITY; TAN - LIGHT BROWN; MEDIUM; WET; VERY LIMY, WITH SCATTERED GRAVEL 19.5' TO 20.8' ± GRAVEL: FINE - MEDIUM; CHERT & L.S.; LIGHT BROWN; MEDIUM, LIMY; SATURATED; CLAYEY 20.8' ± TO 33.0' ± CLAY SHALE: HIGHLY WEATHERED, YELLOWISH BROWN WITH LIGHT GRAY, SOFT; DAMP; CALCAREOUS, MEDIUM-HIGH PLASTICITY 33.0' ± TO 44.0' SHALE (MARL): UN-WEATHERED, MEDIUM DARK GRAY; SOFT - MODERATELY SOFT WITH SCATTERED HARD LIMY SEAMS; DRY - DAMP; CALCAREOUS		8" FLIGHT AUGER	4. NOTE: GAMMA LOG & CALIPER LOG WERE RUN IN BORING ON 30 AUG 84. RESISTIVITY PROBE DID NOT FUNCTION PROPERLY
	40					

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT) | PROJECT: SAN PEDRO TUNNEL | HOLE NO. 3F-296

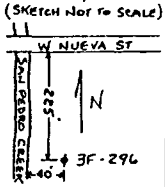
DL-186

Hole No. 3F-296

DRILLING LOG | DIVISION | INSTALLATION | SHEET 2 OF 5 SHEETS

1. PROJECT: SAN PEDRO TUNNEL, SAN ANTONIO, TX.
2. LOCATION (Coordinates or Station)
3. DRILLING AGENCY
4. HOLE NO. (As shown on drawing title and file number): 3F-296
5. NAME OF DRILLER
6. DIRECTION OF HOLE: ☐ VERTICAL ☐ INCLINED ______ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN
8. DEPTH DRILLED INTO ROCK
9. TOTAL DEPTH OF HOLE
10. SIZE AND TYPE OF BIT
11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
12. MANUFACTURER'S DESIGNATION OF DRILL
13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: DISTURBED | UNDISTURBED
14. TOTAL NUMBER CORE BOXES
15. ELEVATION GROUND WATER
16. DATE HOLE: STARTED 27 AUG 84 | COMPLETED 29 AUG 84
17. ELEVATION TOP OF HOLE
18. TOTAL CORE RECOVERY FOR BORING %
19. SIGNATURE OF INSPECTOR: [signature]

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
			44.0' TO 180.0' TD SHALE (MARL) (FISHTAILED)			5 BORING LOCATION: NOTE BORING WAS DRILLED ON SARA PROPERTY (SKETCH NOT TO SCALE)
	60					
	80					



ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT)

PROJECT: SAN PEDRO TUNNEL | HOLE NO. 3F-296

DL-187

Hole No. 3F-296

DRILLING LOG	DIVISION	INSTALLATION	SHEET 3 OF 5 SHEETS

1. PROJECT: SAN PEDRO TUNNEL, SAN ANTONIO, TX	10. SIZE AND TYPE OF BIT
2. LOCATION (Coordinates or Station)	11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
3. DRILLING AGENCY	12. MANUFACTURER'S DESIGNATION OF DRILL
4. HOLE NO. (As shown on drawing title and file number): 3F-296	13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN — DISTURBED / UNDISTURBED
5. NAME OF DRILLER	14. TOTAL NUMBER CORE BOXES
	15. ELEVATION GROUND WATER
6. DIRECTION OF HOLE: [ ] VERTICAL [ ] INCLINED ____ DEG. FROM VERT.	16. DATE HOLE — STARTED: 27 AUG. 84 — COMPLETED: 29 AUG 84
	17. ELEVATION TOP OF HOLE
7. THICKNESS OF OVERBURDEN	18. TOTAL CORE RECOVERY FOR BORING %
8. DEPTH DRILLED INTO ROCK	19. SIGNATURE OF INSPECTOR: Jackie R. [signature]
9. TOTAL DEPTH OF HOLE	

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	100				5 7/8" FISHTAIL BIT	
	120					

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT) PROJECT: SAN PEDRO TUNNEL HOLE NO. 3F-296

DL-188

Hole No. 3F-296

DRILLING LOG	DIVISION	INSTALLATION	SHEET 4 OF 5 SHEETS

1. PROJECT: SAN PEDRO TUNNEL, SAN ANTONIO, TX.	10. SIZE AND TYPE OF BIT
2. LOCATION (Coordinates or Station)	11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
3. DRILLING AGENCY	12. MANUFACTURER'S DESIGNATION OF DRILL
4. HOLE NO. (As shown on drawing title and file number): 3F-296	13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN — DISTURBED — UNDISTURBED
5. NAME OF DRILLER	14. TOTAL NUMBER CORE BOXES
6. DIRECTION OF HOLE: [ ] VERTICAL [ ] INCLINED ____ DEG. FROM VERT.	15. ELEVATION GROUND WATER
7. THICKNESS OF OVERBURDEN	16. DATE HOLE — STARTED 27 AUG 84 — COMPLETED 29 AUG. 84
8. DEPTH DRILLED INTO ROCK	17. ELEVATION TOP OF HOLE
9. TOTAL DEPTH OF HOLE	18. TOTAL CORE RECOVERY FOR BORING %
	19. SIGNATURE OF INSPECTOR: Jackie R. [signature]

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	140					
	160					

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT)

PROJECT: SAN PEDRO TUNNEL — HOLE NO. 3F-296

DL-189

Hole No 3F-296

DRILLING LOG	DIVISION	INSTALLATION	SHEET 5 OF 5 SHEETS

1. PROJECT SAN PEDRO TUNNEL, SAN ANTONIO, TX	10. SIZE AND TYPE OF BIT
2. LOCATION (Coordinates or Station)	11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
3. DRILLING AGENCY	12. MANUFACTURER'S DESIGNATION OF DRILL
4. HOLE NO. (As shown on drawing title and file number) 3F-296	13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: DISTURBED / UNDISTURBED
5. NAME OF DRILLER	14. TOTAL NUMBER CORE BOXES
6. DIRECTION OF HOLE: ☐ VERTICAL ☐ INCLINED ____ DEG. FROM VERT.	15. ELEVATION GROUND WATER
7. THICKNESS OF OVERBURDEN	16. DATE HOLE: STARTED 27 AUG 84 / COMPLETED 29 AUG 84
8. DEPTH DRILLED INTO ROCK	17. ELEVATION TOP OF HOLE
9. TOTAL DEPTH OF HOLE	18. TOTAL CORE RECOVERY FOR BORING %
	19. SIGNATURE OF INSPECTOR Jackie K. Stokes

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	180.0		T.D. 180.0'			
	200					

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT) | PROJECT SAN PEDRO TUNNEL | HOLE NO. 3F-296

Hole No. 6DC-302

DRILLING LOG	DIVISION SWD	INSTALLATION FWD	SHEET 1 OF 5 SHEETS

1. PROJECT: SAN PEDRO TUNNEL, SAN ANTONIO, TX.
2. LOCATION (Coordinates or Station): STA. 141+32
3. DRILLING AGENCY: USCE
4. HOLE NO. (As shown on drawing title and file number): 6DC-302
5. NAME OF DRILLER: T. SUITS
6. DIRECTION OF HOLE: [X] VERTICAL [ ] INCLINED ___ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN: 29.5'±
8. DEPTH DRILLED INTO ROCK: 150.5'±
9. TOTAL DEPTH OF HOLE: 180.0'
10. SIZE AND TYPE OF BIT: 6" CARBOLOY
11. DATUM FOR ELEVATION SHOWN (TBM or MSL):
12. MANUFACTURER'S DESIGNATION OF DRILL: FAILING 1500
13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: DISTURBED 9, UNDISTURBED 8
14. TOTAL NUMBER CORE BOXES: 27
15. ELEVATION GROUND WATER: SEE REMARKS COLUMN
16. DATE HOLE: STARTED 27 MAR 86, COMPLETED 8 APRIL 86
17. ELEVATION TOP OF HOLE: 648
18. TOTAL CORE RECOVERY FOR BORING: 99%
19. SIGNATURE OF INSPECTOR: [signature]

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)
	0.0		0.0 TO 0.3': GRAVEL BASE			1 WATER LEVEL: NOTE SOME FREE WATER IN MATERIAL FROM 12.0'-17.3, MATERIAL SATURATED FROM 19.0-25.0
			0.3 TO 4.0 CLAY FILL: 0.3-1.4': MEDIUM-HIGH PLASTICITY; DARK BROWN; HARD; DAMP; CALCAREOUS; WITH SCATTERED GRAVEL		Bag 1	
			1.4-4.0': MEDIUM PLASTICITY, YELLOWISH BROWN, HARD, DAMP; SILTY; VERY CALCAREOUS; WITH LIME NODULES		DB 1 (4.50) DB 2 (4.00)	
			4.0' TO 8.0±: CLAY MEDIUM-HIGH PLASTICITY; BLACK, VERY STIFF, DAMP; CALCAREOUS, WITH OCCASIONAL GRAVEL		DB 3 DB 4 (4.00)	2 JAR SAMPLES: A: 29.5'-31.5'
			8.0± TO 10.0±: SILT: LOW PLASTICITY; LIGHT GRAYISH BROWN; HARD; DAMP; CALCAREOUS; SANDY		DB 5 (1.00) DB 6 (1.50)	3 DENISON SAMPLES: DB1: 4.5'-6.5; 2: 6.5'-8.5; 3: 8.5'-10.5'; 4: 10.5'-12.5; 5: 12.5'-14.5; 6: 14.5-16.5'; 7: 16.5-18.5; 8: 18.5-20.5
			10.0± TO 19.0±: CLAY: 10.0'±-12.0'±: MEDIUM PLASTICITY, LIGHT BROWN, VERY STIFF-HARD, DAMP, SILTY; VERY CALCAREOUS, WITH LARGE NODULAR L.S GRAVEL		DB 7 (3.00) DB 8	
	20		12.0±-17.3'±: MEDIUM PLASTICITY, LIGHT BROWN, MEDIUM-STIFF; VERY MOIST, VERY CALCAREOUS; WITH NODULAR L.S GRAVEL		DIS-TURBED BAG 1	3 CARTON SAMPLES: C-1: 31.5-32.5; 2: 36.3-37.3'; 3: 41.3'-45.3; 4: 49.7-50.7; 5: 55.6-56.6'; 6: 60.7-61.7; 7: 66.1'-67.1; 8: 71.5'-72.5; 9: 77.5-78.5; 10: 84.5'-85.5; 11: 90.1'-91.1; 12: 96.1-97.1'; 13: 102.5'-103.5'; 14: 108.5'-109.5; 15: 114.5-115.5'; 16: 120.5-121.5'; 17: 126.2-127.2; 18: 132.2-133.2'; 19: 138.5-139.5; 20: 144.3'-145.3; 21: 149.6-150.6'; 22: 156.0'-157.0; 23: 163.5-164.5'; 24: 169.9-170.9; 25: 176.4-177.4
			17.3'-19.0'±: MEDIUM PLASTICITY; LIGHT GRAY WITH YELLOWISH BROWN; VERY STIFF; DAMP; SILTY; VERY CALCAREOUS; WITH LIME POCKETS		NO SAMPLE	
	29.5		19.0'± TO 21.5'±: SAND: FINE GRAINED; LIGHT BROWN; DENSE; DAMP, SILTY, WITH FERRUGINOUS STAINS, VERY CALCAREOUS	31.5	A	
			21.5'± TO 25.0'±: GRAVEL: ROUNDED NODULAR L.S GRAVEL; MEDIUM-LARGE, SATURATED, MEDIUM, VERY CLAYEY; VERY CALCAREOUS, WITH SCATTERED COBBLES (NOTE: BORDERS A	L.O.B 35.5 G:0.6 39.5	1	
	40					

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT)

PROJECT: SAN PEDRO TUNNEL — HOLE NO. 6DC-302

DL-206

Hole No. 6DC-302

DRILLING LOG	DIVISION	INSTALLATION	SHEET 2 OF 5 SHEETS

1. PROJECT: San Pedro Tunnel, San Antonio, Tx.

HOLE NO. (As shown on drawing title and file number): 6DC-302

DATE HOLE: STARTED 27 MAR 86 · COMPLETED 8 APRIL 86

SIGNATURE OF INSPECTOR: [illegible signature]

Elevation	Depth	Legend	Classification of Materials	% Core Recovery	Box or Sample No.	Remarks
			GRAVELLY CLAY)	L:1.3	2	4. BAG SAMPLES: B-1: 22.5'-25.0'
			25.0'± TO 29.5'± CLAY (RE-WORKED PRIMARY): MEDIUM-HIGH PLASTICITY; YELLOWISH BROWN; VERY STIFF; DAMP; VERY CALCAREOUS; GRAVELLY; (NOTE: UNABLE TO OBTAIN REPRESENTATIVE SAMPLE DUE TO GRAVEL & WATER IN BORING)	43.5		5. DRILLING: 10" FLIGHT AUGER: 0.0' - 4.0' NOTE: SET 8" STEEL CASING TO 4.0'
		3		L:0.8 / 47.0	3	8" FLIGHT AUGER: 4.0' - 4.5' (CLEANOUT) 6" DENISON BARREL: 4.5' - 22.5'
		4	29.5'± TO 39.3'± CLAY SHALE: BADLY WEATHERED; MEDIUM-HIGH PLASTICITY; YELLOWISH BROWN WITH LIGHT GRAY; SOFT; DAMP; CALCAREOUS; WITH LIME POCKETS; SLIGHTLY SILTY; WITH FERRUGINOUS STAINS; WITH LIME CONCRETIONS AT 34.0', 34.3' & 37.6; HIGHLY FRACTURED WITH WELL HEALED FRACTURES THROUGHOUT	L:0.0 / 50.5 / L:0.1 / 54.5	4	NOTE: SAMPLE WAS DISTURBED FROM 20.5' - 22.5' DUE TO GRAVEL NOTE: PULLED 4.0 STEEL CASING, BAILED BORING & REAMED WITH AUGER 10" FLIGHT AUGER: 22.5' - 30.5'
		5		G:0.3 / 58.5	5	NOTE: RESET 8" STEEL CASING TO 30.5' 8" FLIGHT AUGER: 30.5' - 31.5'
	60	6	39.3'± TO 180.0' T.D. SHALE (MARL): UNWEATHERED; DARK GRAY (NOTE: DRIES TO A LIGHT BLUISH GRAY); VERY CALCAREOUS; SILTY; SOFT-MODERATELY SOFT WITH OCCASIONAL MODERATELY SOFT-MODERATELY HARD SEAM; WITH NO FRACTURES OBSERVED IN CORE; DRY-DAMP; FOSSILIFEROUS; WITH SMALL AMOUNT OF HYDROCARBON RESIDUE IN DRILL FLUID; WITH OCCASIONAL PYRITE NUGGET	L:0.0 / 62.5 / G:0.2 / 66.5	6	6" CORE BARREL: 31.5' - 43.5' NOTE: PULLED 8' STEEL CASING, BAILED BORING, SET 8" PVC CASING TO 43.5' & GROUTED IN PLACE AFTER ALLOWING CEMENT TO HARDEN OVERNIGHT, CEMENT PLUG WAS DRILLED OUT
		7		G:0.3 / 70.5	7	6" CORE BARREL: 43.5' - 180.0'
		8	39.6' - 40.6: LIMY 44.3': LIMY 45.3' - 48.6': SOFT; CRACKS SLIGHTLY UPON EXPOSURE	G:0.1 / 74.5 / L:0.0	8	6. NOTE: GAMMA & RESISTIVITY LOGS WERE RUN IN BORING ON 11 APR 86
	80	9	48.6' - 51.6: MODERATELY SOFT; LIMY	78.5		

ENG FORM 1836 MAR 71 · PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT)

PROJECT: SAN PEDRO TUNNEL · HOLE NO. 6DC-302

DL-207

Hole No. 6DC-302

DRILLING LOG

SHEET 3 OF 5 SHEETS

1. PROJECT: San Pedro Tunnel, San Antonio, Tx.

HOLE NO.: 6DC-302

DATE HOLE: STARTED 27 MAR. 86 | COMPLETED 8 APRIL 86

SIGNATURE OF INSPECTOR: Jackie K. [illegible]

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS
			51.6'-84.9': SOFT; CRACKS SLIGHTLY UPON EXPOSURE	L:0.0 / 82.5	9	
			84.9'-86.4': VERY SOFT; VERY SILTY; WITH TRACE OF FINE SAND	L:0.0 / 86.5	10	
			86.4'-103.2': SOFT-MODERATELY SOFT; SILTY; WITH TRACE OF FINE SAND	L:0.4 / 90.5	11	
				G:0.4 / 94.3		
				L:0.0 / 98.5	12	
	100			L:0.0 / 102.5	13	
			103.2'-108.8': VERY SOFT; WITH SOME HYDROCARBON ODOR	L:0.0 / 106.5		
			108.8'-108.9': THIN LIGHT GRAY BAND; SLIGHTLY WAXY	L:0.0	14	
			108.9'-114.0': SOFT-MODERATELY SOFT; LIMY	110.5		
				L:0.8	15	
			114.0'-118.4': SOFT; SLIGHTLY GUMMY; CRACKS SLIGHTLY UPON EXPOSURE	114.5 / G:0.3		
	120		118.4'-121.5': SOFT-MODERATELY SOFT; LIMY	118.5	16	

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT)

PROJECT: SAN PEDRO TUNNEL | HOLE NO.: 6DC-302

DL-208

Hole No. GDC-302

DRILLING LOG — Sheet 4 of 5 sheets

1. PROJECT: SAN PEDRO TUNNEL, SAN ANTONIO, TX.

HOLE NO.: GDC-302

DATE HOLE: STARTED 27 MAR. 86; COMPLETED 8 APRIL 86

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS
			121.5'-130.0': SOFT; SLIGHTLY WAXY; CRACKS SLIGHTLY UPON EXPOSURE	G:0.5'		
				122.5	17	
				L:0.3		
				126.5	18	
				L:0.0'		
			130.0'-134.5': SOFT-MODERATELY SOFT; SILTY; LIMY	130.5		
			134.5'-135.5': SOFT-MODERATELY SOFT, VERY LIMY	L:0.0'		
			135.5'-158.2': SOFT; CRACKS SLIGHTLY UPON EXPOSURE	134.5	19	
				G 0.3'		
				138.5		
	140			L:0.0'	20	
				142.5		
				L:0.0'		
				146.5	21	
				L:0.9'		
				150.5		
			152.0 & 153.5': FOSSIL CASTS	G:0.9	22	
			153.5': MECHANICAL BREAK	153.5		
			157.8: "			
				L:0.0'		
			158.2-159.3: MODERATELY SOFT-MODERATELY HARD, VERY LIMY	157.8	23	
	160			L:0.0'		

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT)

PROJECT: SAN PEDRO TUNNEL — HOLE NO. GDC 302

DL-209

Hole No. 6DC-302

DRILLING LOG	DIVISION	INSTALLATION	SHEET 5 OF 5 SHEETS

1. PROJECT: SAN PEDRO TUNNEL, SAN ANTONIO, TX.
2. LOCATION (Coordinates or Station)
3. DRILLING AGENCY
4. HOLE NO. (As shown on drawing title and file number): 6DC-302
5. NAME OF DRILLER
6. DIRECTION OF HOLE: ☐ VERTICAL ☐ INCLINED ______ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN
8. DEPTH DRILLED INTO ROCK
9. TOTAL DEPTH OF HOLE
10. SIZE AND TYPE OF BIT
11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
12. MANUFACTURER'S DESIGNATION OF DRILL
13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN | DISTURBED | UNDISTURBED
14. TOTAL NUMBER CORE BOXES
15. ELEVATION GROUND WATER
16. DATE HOLE: STARTED 27 MAR 86 COMPLETED 8 APRIL 86
17. ELEVATION TOP OF HOLE
18. TOTAL CORE RECOVERY FOR BORING %
19. SIGNATURE OF INSPECTOR: Jackie K. Stokes

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
			159.3'-162.2': SOFT; SLIGHTLY WAXY			
			162.2'-167.0': MODERATELY SOFT; LIMY	162.1	24	
		23	163.5': FOSSIL CAST	L:0.0'		
			167.0'-179.0': SOFT; SLIGHTLY WAXY	167.3	25	
		24		L.0.1'		
				171.0		
				L:0.1'	26	
		25		176.0		
			179.0'-180.0': MODERATELY SOFT; VERY LIMY	G:0.2	27	
	180.0		T.D. 180.0'	180.0		
	200					

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT)

PROJECT: SAN PEDRO TUNNEL

HOLE NO. 6DC-302

DL-210

Hole No. 6A4C-303

DRILLING LOG	DIVISION: SWD	INSTALLATION: FWD	SHEET 1 of 5 SHEETS

1. PROJECT: SAN PEDRO TUNNEL, SAN ANTONIO, TX.
2. LOCATION (Coordinates or Station): SEE LAYOUT
3. DRILLING AGENCY: USCE
4. HOLE NO. (As shown on drawing title and file number): 6A4C-303
5. NAME OF DRILLER: K BROTHERS (HAMILTON)
6. DIRECTION OF HOLE: ☒ VERTICAL ☐ INCLINED ______ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN: 18.2'
8. DEPTH DRILLED INTO ROCK: 161.8'
9. TOTAL DEPTH OF HOLE: 180.0'
10. SIZE AND TYPE OF BIT: 4" CARBOLOY
11. DATUM FOR ELEVATION SHOWN (TBM or MSL):
12. MANUFACTURER'S DESIGNATION OF DRILL: DAMCO 1250
13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED 7 | UNDISTURBED 0
14. TOTAL NUMBER CORE BOXES:
15. ELEVATION GROUND WATER: SEE REMARKS COLUMN
16. DATE HOLE: STARTED 21 AUG 85 | COMPLETED 29 AUG 85
17. ELEVATION TOP OF HOLE:
18. TOTAL CORE RECOVERY FOR BORING: 99 %
19. SIGNATURE OF INSPECTOR: Jackie R. Stokes

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	0.0		0.0 TO 5.1'± FILL: 0.0 - 3.0'±: GRAVEL FILL: GRADED, ANGULAR, MEDIUM, DRY, CLAYEY, LIGHT BROWN, LIMY; WITH ASPHALT FRAGMENTS		A, B	1. WATER LEVEL: NOTE: FREE WATER ENTERING BORING AT 13.0'
			3.0'± - 5.1'± CLAY FILL: MEDIUM PLASTICITY; YELLOWISH BROWN & LIGHT GRAY, HARD, DAMP; VERY LIMY, WITH LARGE GRAVEL & COBBLES		C, D	2. JAR SAMPLES: A: 0.0 - 3.0; B: 3.0' - 5.1'; C: 5.1' - 6.0'; D: 6.0' - 9.0'; E: 9.0' - 13.0'; F: 13.0' - 15.0'; G: 15.0 - 18.2; H: 18.2' - 23.0
			5.1'± TO 13.0' CLAY: 5.1'± - 6.0': MEDIUM-HIGH PLASTICITY, DARK BROWN, STIFF, MOIST, CALCAREOUS, WITH LIME NODULES		E	3. CARTON SAMPLES: C-1: 25.0 - 26.0; 2: 31.0 - 32.0; 3: 37.0 - 38.0'; 4: 45.0' - 46.0; 5: 51.6' - 52.6; 6: 58.4' - 59.4; 7: 63.7' - 64.7; 8: 69.5' - 70.5; 9: 77.0' - 78.0'; 10: 83.7' - 84.7; 11: 91.1 - 92.1'; 12: 98.4' - 99.4; 13: 105.0' - 106.0; 14: 111.4 - 112.4; 15: 117.3' - 118.3; 16: 123.2 - 124.2; 17: 129.3 - 130.2; 18: 135.0 - 136.0'; 19: 140.7' - 141.7; 20: 146.6 - 147.6; 21: 152.3 - 153.3; 22: 159.2 - 160.1; 23: 165.0' - 166.0; 24: 171.1' - 172.1; 25: 176.2 - 177.2
			6.0' - 9.0': MEDIUM-HIGH PLASTICITY, BLACK, VERY STIFF; DAMP - SLIGHTLY MOIST; CALCAREOUS		F	
			9.0' - 13.0': MEDIUM HIGH PLASTICITY; LIGHT GRAY WITH YELLOWISH BROWN, VERY STIFF, DAMP - SLIGHTLY MOIST; VERY CALCAREOUS, WITH OCCASIONAL LIME GRAVEL		G	
	18.2					
	20		13.0' TO 15.0 GRAVEL: GRADED: LIMESTONE; ROUNDED; MEDIUM, VERY MOIST, VERY LIMY, CLAYEY	23.0	H	
		1	15.0 TO 18.2'±: CLAY (MUCK): MEDIUM-HIGH PLASTICITY; LIGHT BROWN, MEDIUM, WET, VERY LIMY; GRAVELLY	L: 0.5; 27.5	1	
		2	18.2'± TO 44.3' CLAY SHALE: BADLY WEATHERED, YELLOWISH BROWN & LIGHT GRAY; SOFT, DAMP; MEDIUM-HIGH PLASTICITY, SLIGHTLY SILTY, CALCAREOUS, HIGHLY FRACTURED WITH POORLY DEVELOPED FRACTURES, WITH OCCASIONAL POORLY HEALED FRACTURE FROM 32.0 - 44.3'	L: 0.0; 32.5	2	4. DRILLING: 10" FLIGHT AUGER: 0.0 - 22.0; NOTE: SET 8" STEEL CASING TO 22.0; 8" FLIGHT AUGER: 22.0 - 23.0'; 4" CORE BARREL: 23.0 - 55.0; NOTE: REAMED BORING & SET 6" PVC PIPE TO 55.0 ↓
	40	3		L: 0.5; 37.5	3	

ENG FORM 1836, MAR 71 — PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT)

PROJECT: SAN PEDRO | HOLE NO. 6A4C-303

DL-211

Hole No. 6A4C-303

DRILLING LOG	DIVISION	INSTALLATION	SHEET 2 of 5 SHEETS
1. PROJECT: SAN PEDRO TUNNEL, SAN ANTONIO, TX.		10. SIZE AND TYPE OF BIT	
2. LOCATION (Coordinates or Station)		11. DATUM FOR ELEVATION SHOWN (TBM or MSL)	
3. DRILLING AGENCY		12. MANUFACTURER'S DESIGNATION OF DRILL	
4. HOLE NO. (As shown on drawing title and file number): 6A4C-303		13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN	DISTURBED / UNDISTURBED
5. NAME OF DRILLER		14. TOTAL NUMBER CORE BOXES	
6. DIRECTION OF HOLE: ☐ VERTICAL ☐ INCLINED ___ DEG. FROM VERT.		15. ELEVATION GROUND WATER	
7. THICKNESS OF OVERBURDEN		16. DATE HOLE	STARTED 21 AUG 85 / COMPLETED 29 AUG. 85
8. DEPTH DRILLED INTO ROCK		17. ELEVATION TOP OF HOLE	
9. TOTAL DEPTH OF HOLE		18. TOTAL CORE RECOVERY FOR BORING	%
		19. SIGNATURE OF INSPECTOR: Jackie R. Stokes	

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
				L:0 5 / 42 0		GROUTED IN PLACE & PULLED 8" STEEL CASING; 4" CORE BARREL 55.0' - 180.0'
		4	44.3' TO 180.0' T.D. SHALE (MARL) - UNWEATHERED, DARK GRAY (DRIES TO A LIGHTER GRAY), SOFT-MODERATELY WITH AN OCCASIONAL MODERATELY HARD, VERY LIMY SEAM; CALCAREOUS, WITH SCATTERED FOSSIL CASTS & PYRITE NUGGETS; BREAKS PREDOMINANTLY WITH A CONCHOIDAL FRACTURE, WITH NO FRACTURES OBSERVED IN CORE	6 0 5 / 46.0	4	5. NOTE. GAMMA & RESISTIVITY LOGS WERE RUN IN BORING ON 29 AUG. 85
		5		L:0.0 / 50.5	5	
				L:0.0 / 55.0	6	
	60	6		L.02 / 60 0		
		7		L:0.0 / 65 0	7	
		8		L:03 / 69.5	8	
				6:0 5 / 73.5	9	
		9	75.0'± - 98.0'± MODERATELY SOFT	L 0 0 / 77.0		
	80			L:0 0	10	

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT) — PROJECT: SAN PEDRO — HOLE NO. 6A4C-303

Hole No. 6A4C-303

DRILLING LOG	DIVISION	INSTALLATION	SHEET 3 of 5 SHEETS
1. PROJECT San Pedro Tunnel, San Antonio, Tx.		10. SIZE AND TYPE OF BIT	
2. LOCATION (Coordinates or Station)		11. DATUM FOR ELEVATION SHOWN (TBM or MSL)	
3. DRILLING AGENCY		12. MANUFACTURER'S DESIGNATION OF DRILL	
4. HOLE NO. (As shown on drawing title and file number) 6A4C-303		13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN	DISTURBED / UNDISTURBED
5. NAME OF DRILLER		14. TOTAL NUMBER CORE BOXES	
6. DIRECTION OF HOLE ☐ VERTICAL ☐ INCLINED ____ DEG. FROM VERT.		15. ELEVATION GROUND WATER	
		16. DATE HOLE	STARTED 21 AUG. 85 / COMPLETED 29 AUG 85
7. THICKNESS OF OVERBURDEN		17. ELEVATION TOP OF HOLE	
8. DEPTH DRILLED INTO ROCK		18. TOTAL CORE RECOVERY FOR BORING %	
9. TOTAL DEPTH OF HOLE		19. SIGNATURE OF INSPECTOR Jackie R. Stokes	

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
				81.0		
			81.3'-82.6' MECHANICAL BREAK IN CORE			
		10		L.0.2	11	
				86.0		
			88.9-90.5 MECHANICAL BREAK IN CORE	G.0.2	12	
				90.5		
		11		L:0.2		
				94.5	13	
				L:0.2		
			97.6-98.4 MECHANICAL BREAK IN CORE	98.0		
		12				
	100			L:0.0	14	
				101.5		
			104.0'±-110.0'± MODERATELY HARD, VERY LIMY	G:0.4		
		13		106.0	15	
			107.6' PYRITE NUGGET			
				L.1.0		
			110.0'±-114.0' SOFT, SLIGHTLY WAXY	111.0		
			110.0'-110.1' MECHANICAL BREAK		16	
		14	110.9-111.4 MECHANICAL BREAK	G:0.8		
			114.0'±-117.0' MODERATELY HARD; VERY LIMY	114.5		
			117.0'±-123.0'± SOFT, SILTY	L:0.0	17	
		15		118.5		
	120					

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT) | PROJECT SAN PEDRO | HOLE NO. 6A4C-303

DL-213

Hole No. 6A4C-303

DRILLING LOG	DIVISION	INSTALLATION	SHEET 2 of 5 SHEETS

1. PROJECT: SAN PEDRO TUNNEL, SAN ANTONIO, TX.
2. LOCATION (Coordinates or Station):
3. DRILLING AGENCY:
4. HOLE NO. (As shown on drawing title and file number): 6A4C-303
5. NAME OF DRILLER:
6. DIRECTION OF HOLE: ☐ VERTICAL ☐ INCLINED ______ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN:
8. DEPTH DRILLED INTO ROCK:
9. TOTAL DEPTH OF HOLE:
10. SIZE AND TYPE OF BIT:
11. DATUM FOR ELEVATION SHOWN (TBM or MSL):
12. MANUFACTURER'S DESIGNATION OF DRILL:
13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED | UNDISTURBED
14. TOTAL NUMBER CORE BOXES:
15. ELEVATION GROUND WATER:
16. DATE HOLE: STARTED 21 AUG 85 | COMPLETED 29 AUG 85
17. ELEVATION TOP OF HOLE:
18. TOTAL CORE RECOVERY FOR BORING %:
19. SIGNATURE OF INSPECTOR: Jack L. Stokes

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
				L.0.0		
		16		123.0	18	
				G.0.2		
			126.0'±-135.0'±: MODERATELY HARD, LIMY	126.5		
				L.0.0	19	
		17	130.2'-131.5': MECHANICAL BREAK	130.2		
				L.0.0	20	
				135.0		
		18		L.0.2	21	
	140			140.0		
		19		L.0.0	22	
				145.0		
			146.6': FOSSIL CAST			
		20		L.0.0	23	
			149.3': " "	149.5		
				L.0.0		
		21	153.0±-157.0±: MODERATELY HARD, VERY LIMY	152.5	24	
				G.0.2		
			158.0±-163.0±: MODERATELY HARD, VERY LIMY	157.5		
	160	22		L.1.0		

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT)

PROJECT: SAN PEDRO | HOLE NO. 6A4C-303

DL-214

Hole No. 6A4C-303

DRILLING LOG	DIVISION	INSTALLATION	SHEET 5 OF 5 SHEETS

1. PROJECT: San Pedro Tunnel, San Antonio, Tx.	10. SIZE AND TYPE OF BIT
2. LOCATION (Coordinates or Station)	11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
3. DRILLING AGENCY	12. MANUFACTURER'S DESIGNATION OF DRILL
4. HOLE NO. (As shown on drawing title and file number): 6A4C-303	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN — DISTURBED — UNDISTURBED
5. NAME OF DRILLER	14. TOTAL NUMBER CORE BOXES
6. DIRECTION OF HOLE: ☐ VERTICAL ☐ INCLINED ____ DEG. FROM VERT.	15. ELEVATION GROUND WATER
	16. DATE HOLE — STARTED 21 AUG. 85 — COMPLETED 29 AUG. 85
7. THICKNESS OF OVERBURDEN	17. ELEVATION TOP OF HOLE
8. DEPTH DRILLED INTO ROCK	18. TOTAL CORE RECOVERY FOR BORING %
9. TOTAL DEPTH OF HOLE	19. SIGNATURE OF INSPECTOR: [signature]

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
			160.4': FOSSIL CAST		25	
				162.0		
				C:1.0		
		23		165.0	26	
				L:0.2		
				169.0		
				6:0.2	27	
		24		173.0		
				L:0.3		
		25	177.6': VERY LIMY INCLUSION	177.5	28	
			179.0-180.0': MODERATELY HARD, VERY LIMY	L:0.1		
	180.0		T.D 180.0'	180.0		
	200					

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT)

PROJECT: SAN PEDRO — HOLE NO.: 6A4C-303

DL-215

Hole No. 6A4C-304

DRILLING LOG	DIVISION SWD	INSTALLATION FW	SHEET 1 OF 5 SHEETS

1. PROJECT: SAN PEDRO TUNNEL, SAN ANTONIO, TX.
2. LOCATION (Coordinates or Station): STA. 164+00
3. DRILLING AGENCY: USCE
4. HOLE NO. (As shown on drawing title and file number): 6A4C-304
5. NAME OF DRILLER: T. SUITS
6. DIRECTION OF HOLE: [X] VERTICAL [ ] INCLINED ____ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN: 21.0
8. DEPTH DRILLED INTO ROCK: 144.0
9. TOTAL DEPTH OF HOLE: 165.0
10. SIZE AND TYPE OF BIT: 5 1/2" CARBOLOY
11. DATUM FOR ELEVATION SHOWN (TBM or MSL):
12. MANUFACTURER'S DESIGNATION OF DRILL: FAILING 1500
13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED 0 / UNDISTURBED 0
14. TOTAL NUMBER CORE BOXES: 17
15. ELEVATION GROUND WATER: SEE REMARKS COLUMN
16. DATE HOLE: STARTED 17 MAR 86 / COMPLETED 27 MAR 86
17. ELEVATION TOP OF HOLE:
18. TOTAL CORE RECOVERY FOR BORING: 100%
19. SIGNATURE OF INSPECTOR: Jack R. Stokes

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	0.0		0.0 To 0.1 ASPHALT PAVEMENT 0.1' To 1.0' GRAVEL BASE 1.0' To 3.5' CLAY FILL: LOW PLASTICITY, DARK BROWN; STIFF, DAMP, VERY SILTY; WITH SOME SMALL METAL FRAGMENTS 3.5' To 4.2' GRAVEL: MEDIUM-LARGE; L.S., MEDIUM COMPACTION, DAMP; CLAYEY 4.2' To 21.0' CLAY: 4.2'-11.0': MEDIUM-HIGH PLASTICITY; DARK GRAY, MEDIUM-STIFF; MOIST, SILTY 11.0-18.0': MEDIUM-HIGH PLASTICITY; YELLOWISH BROWN & LIGHT GRAY, STIFF; DAMP-MOIST, SILTY, WITH CALCAREOUS NODULES 18.0'-19.5': LOW PLASTICITY, YELLOWISH BROWN & LIGHT GRAY, MEDIUM, SATURATED, CALCAREOUS, WITH COBBLES 19.5'-21.0 (RE-WORKED PRIMARY); LIGHT GRAY & YELLOWISH BROWN, STIFF; DAMP, VERY SILTY, CALCAREOUS		10" FLIGHT AUGER	1. WATER LEVEL: NOTE: FREE WATER WAS ENTERING BORING DURING AUGERING FROM 16.3± 2. CARTON SAMPLES C 1 100.0 - 101.0 2 105.8' - 106.8' 3 111.0' - 112.0 4 116.7 - 117.7 5 122.5 - 123.5 6 128.2 - 129.2 7 133.6' - 134.6 8 139.0' - 140.0 9 144.7' - 145.7 10 150.7' - 151.7 11 156.1' - 157.1 12 161.0 - 162.0
	20 21.0		21.0' To 32.0' CLAY SHALE: BADLY WEATHERED, YELLOWISH BROWN & LIGHT GRAY, SOFT, DAMP, CALCAREOUS, SILTY, MEDIUM HIGH PLASTICITY		8" FLIGHT AUGER	3. DRILLING: 10" FLIGHT AUGER: 0.0' - 23.0 NOTE: SET 8" STEEL CASING TO 23.0' 8" FLIGHT AUGER: 23.0' - 40.5' NOTE: SET 6" PVC PIPE TO 40.5 & GROUTED IN PLACE & PULLED 8" STEEL CASING; NOTE: CEMENT ALLOWED TO SET UP 5 7/8" FISHTAIL 40.5' - 100.0 5 1/2" CORE BARREL 100.0 - 165.0
	40		32.0 To 165.0 T.D. SHALE (MARL): UNWEATHERED, DARK GRAY (DRIES TO A LIGHT GRAY), SOFT-MODERATELY SOFT WITH OCCASIONAL MODERATELY HARD SEAM, DRY-DAMP, CALCAREOUS, FOSSILIFEROUS, MODERATELY SILTY-SILTY, WITH SCATTERED PYRITE CONCENTRATIONS; BREAKS PREDOMINANTLY WITH A			4. NOTE: BORING WAS E-LOGGED ON 31 MAR 86; BORING TO BE BAILED AT A LATER DATE

ENG FORM 1836, MAR 71 — PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT) — PROJECT: SAN PEDRO TUNNEL — HOLE NO. 6A4C-304

DL-216

Hole No. 6A4C-304

DRILLING LOG	DIVISION	INSTALLATION	SHEET 2 OF 5 SHEETS

1. PROJECT SAN PEDRO TUNNEL, SAN ANTONIO, TX.	10. SIZE AND TYPE OF BIT
2. LOCATION (Coordinates or Station)	11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
3. DRILLING AGENCY	12. MANUFACTURER'S DESIGNATION OF DRILL
4. HOLE NO. (As shown on drawing title and file number) 6A4C-304	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN — DISTURBED — UNDISTURBED
5. NAME OF DRILLER	14. TOTAL NUMBER CORE BOXES
	15. ELEVATION GROUND WATER
6. DIRECTION OF HOLE ☐ VERTICAL ☐ INCLINED ___ DEG. FROM VERT.	16. DATE HOLE — STARTED 17 MAR. 86 — COMPLETED 27 MAR 86
	17. ELEVATION TOP OF HOLE
7. THICKNESS OF OVERBURDEN	18. TOTAL CORE RECOVERY FOR BORING %
8. DEPTH DRILLED INTO ROCK	19. SIGNATURE OF INSPECTOR Jackie R. Stokes
9. TOTAL DEPTH OF HOLE	

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
			CONCHOIDAL FRACTURE; WITH NO FRACTURES OBSERVED IN CORED SECTION			
	60				5 7/8" FISHTAIL	
	80					

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT)

PROJECT SAN PEDRO TUNNEL — HOLE NO. 6A4C-304

Hole No 6A4C-304

DRILLING LOG	DIVISION	INSTALLATION	SHEET 3 OF 5 SHEETS

1. PROJECT SAN PEDRO TUNNEL, SAN ANTONIO, TX.	10. SIZE AND TYPE OF BIT
2. LOCATION (Coordinates or Station)	11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
3. DRILLING AGENCY	12. MANUFACTURER'S DESIGNATION OF DRILL
4. HOLE NO. (As shown on drawing title and file number) 6A4C-304	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN — DISTURBED — UNDISTURBED
5. NAME OF DRILLER	14. TOTAL NUMBER CORE BOXES
6. DIRECTION OF HOLE ☐ VERTICAL ☐ INCLINED ____ DEG. FROM VERT.	15. ELEVATION GROUND WATER
	16. DATE HOLE — STARTED 27 MAR. 86 — COMPLETED 27 MAR. 86
7. THICKNESS OF OVERBURDEN	17. ELEVATION TOP OF HOLE
8. DEPTH DRILLED INTO ROCK	18. TOTAL CORE RECOVERY FOR BORING %
9. TOTAL DEPTH OF HOLE	19. SIGNATURE OF INSPECTOR Jackie K. Stokes

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	100	1	100.0 - 165.0': CORED SECTION	100.0		
				L:00	1	
		2		108.0	2	
		3	110.8 - 114.2': LIMY, MODERATELY SOFT	L:03	3	
		4		118.0		
	120					

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT)

PROJECT SAN PEDRO TUNNEL — HOLE NO. 6A4C-304

DL-218

Hole No. 6A4C-304

DRILLING LOG	DIVISION	INSTALLATION	SHEET 4 OF 5 SHEETS

1. PROJECT: SAN PEDRO TUNNEL, SAN ANTONIO, TX.
2. LOCATION (Coordinates or Station)
3. DRILLING AGENCY
4. HOLE NO. (As shown on drawing title and file number): 6A4C-304
5. NAME OF DRILLER
6. DIRECTION OF HOLE: ☐ VERTICAL ☐ INCLINED ______ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN
8. DEPTH DRILLED INTO ROCK
9. TOTAL DEPTH OF HOLE
10. SIZE AND TYPE OF BIT
11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
12. MANUFACTURER'S DESIGNATION OF DRILL
13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED | UNDISTURBED
14. TOTAL NUMBER CORE BOXES
15. ELEVATION GROUND WATER
16. DATE HOLE: STARTED 27 MAR 86 | COMPLETED 27 MAR 86
17. ELEVATION TOP OF HOLE
18. TOTAL CORE RECOVERY FOR BORING %
19. SIGNATURE OF INSPECTOR: [signature]

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
			120.5': PYRITE NUGGET		4	
				6:0.2		
		5				
			127.0'-137.2': LIMY, MODERATELY SOFT	126.5	5	
		6				
				L:0.2	6	
		7				
				136.0		
			137.2'-138.6: VERY LIMY; MODERATELY SOFT-MODERATELY HARD		7	
				L:0.3		
	140	8	140.4': FOSSIL CAST			
			141.4': " "			
			142.0-146.7 LIMY, MODERATELY SOFT	142.0	8	
		9				
			146.7': FOSSIL CAST	6:0.6	9	
			150.0'-152.0': WITH SOME HYDROCARBON ODOR & DARK SILT LAMINATIONS & LENSES	150.0		
		10			10	
				L 0.7		
		11				
				158.0	11	
	160					

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT)

PROJECT: SAN PEDRO TUNNEL | HOLE NO. 6A4C 304

DL-219

Hole No. 6A4C-304

DRILLING LOG

Field	Entry
DIVISION	
INSTALLATION	
SHEET	5 OF 5 SHEETS
1. PROJECT	SAN PEDRO TUNNEL, SAN ANTONIO, TX.
2. LOCATION (Coordinates or Station)	
3. DRILLING AGENCY	
4. HOLE NO. (As shown on drawing title and file number)	6A4C-304
5. NAME OF DRILLER	
6. DIRECTION OF HOLE	☐ VERTICAL ☐ INCLINED ___ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN	
8. DEPTH DRILLED INTO ROCK	
9. TOTAL DEPTH OF HOLE	
10. SIZE AND TYPE OF BIT	
11. DATUM FOR ELEVATION SHOWN (TBM or MSL)	
12. MANUFACTURER'S DESIGNATION OF DRILL	
13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN	DISTURBED: — UNDISTURBED: —
14. TOTAL NUMBER CORE BOXES	
15. ELEVATION GROUND WATER	
16. DATE HOLE	STARTED: 17 MAR. 86 COMPLETED: 27 MAR. 86
17. ELEVATION TOP OF HOLE	
18. TOTAL CORE RECOVERY FOR BORING	%
19. SIGNATURE OF INSPECTOR	Jackie L. Stokes

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
		12	160.4'-165.0': VERY LIMY; MODERATELY SOFT-MODERATELY HARD	6:0.7	12	
	165.0		T.D. 165.0'			
	180					
	200					

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT)

PROJECT: SAN PEDRO TUNNEL

HOLE NO. 6A4C-304

DL-220

Hole No. 6A4C-305

DRILLING LOG | DIVISION: SWD | INSTALLATION: SWFWD | SHEET 1 OF 4 SHEETS

PROJECT: San Pedro Tunnel, San Antonio, Tx.

LOCATION: STA. 189+90

DRILLING AGENCY: USCE

HOLE NO.: 6A4C-305

NAME OF DRILLER: T. Silts

DIRECTION OF HOLE: Vertical

THICKNESS OF OVERBURDEN: 7.4'

DEPTH DRILLED INTO ROCK: 157.6'

TOTAL DEPTH OF HOLE: 165.0'

SIZE AND TYPE OF BIT: 4" CARBIDE

MANUFACTURER'S DESIGNATION OF DRILL: FAILING 1500

TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: 6 | 0

TOTAL NUMBER CORE BOXES: 12

ELEVATION GROUND WATER: SEE REMARKS COLUMN

DATE HOLE: STARTED 9 APRIL 86 | COMPLETED 16 APRIL 86

TOTAL CORE RECOVERY FOR BORING: 97%

SIGNATURE OF INSPECTOR: Jack R. Stokes

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS
	0.0		0.0' To 7.4' CLAY: 0.0'-1.0': MEDIUM-HIGH PLASTICITY; DARK BROWN; HARD; DAMP; CALCAREOUS; GRAVELLY 1.0'-5.0': MEDIUM PLASTICITY; LIGHT BROWN, HARD, DAMP, CALCAREOUS, SILTY 5.0'-7.0': MEDIUM-HIGH PLASTICITY; GRAY, VERY STIFF, DAMP; CALCAREOUS 7.0'-7.4': MEDIUM PLASTICITY; GRAY & YELLOWISH BROWN, STIFF, MOIST, GRAVELLY, SILTY, CALCAREOUS		10" AUGER	1. WATER LEVEL: NOTE: A SMALL AMOUNT OF FREE WATER ENTERED BORING DURING AUGERING AT 7.0. BORING WAS BAILED TO 160' AFTER DRILLING & LEFT FOR OBSERVATION 2. JAR SAMPLES: NOTE: NO JAR SAMPLES WERE TAKEN
	7.4		7.4' To 33.0'± CLAY SHALE: BADLY WEATHERED; YELLOWISH BROWN WITH LIGHT GRAY, SOFT, DAMP, CALCAREOUS, MEDIUM-HIGH PLASTICITY; CLAYEY, SLIGHTLY SILTY-SILTY, HIGHLY FRACTURED, WITH FERRUGINOUS STAINING			3. CARTON SAMPLES: C-1: 101.4'-102.4' 2: 107.6'-108.6' 3: 114.6'-115.6' 4: 120.4'-121.4' 5: 127.4'-128.4' 6: 133.5'-134.5' 7: 141.6'-142.6' 8: 146.7'-147.7' 9: 152.5'-153.5' 10: 158.6'-159.6'
	20				8" FLIGHT AUGER	4. DRILLING: 10" FLIGHT AUGER: 0.0'-11.0'. NOTE: SET 8" STEEL CASING TO 11.0. 8" FLIGHT AUGER: 11.0'-40.8'. NOTE: SET 6" PVC PIPE TO 40.8', GROUTED IN PLACE & PULLED 8" STEEL CASING. 5 1/2" ROCKBIT: 40.8-100.0. 4" CORE BARREL: 100.0-165.0
			33.0'± To 165.0' T.D. SHALE (MARL): UNWEATHERED, DARK GRAY (DRIES TO A LIGHT BLUISH GRAY), SOFT-MODERATELY WITH OCCASIONAL MODERATELY SOFT-MODERATELY HARD SEAM, DRY-DAMP, CALCAREOUS; SILTY, WITH SCATTERED PYRITE CONCENTRATIONS, BREAKS WITH A CONCHOIDAL FRACTURE			5. NOTE: A GAMMA LOG & RESISTIVITY LOG WERE RUN IN BORING ON 16 APRIL
	40					

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT)

PROJECT: San Pedro Tunnel | HOLE NO.: 6A4C-305

DL-221

Hole No. 6A4C-305

DRILLING LOG

Sheet 2 of 5 sheets

PROJECT: San Pedro Tunnel, San Antonio, Tx.

HOLE NO.: 6A4C-305

DATE HOLE: Started 19 April '86 — Completed 16 April '86

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS g
			WITH NO FRACTURES OBSERVED IN CORE			
	60				5 1/2" FISHTAIL	
	80					

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT)

PROJECT: SAN PEDRO TUNNEL — HOLE NO. 6A4C-305

DL-222

Hole No. 6A4C-305

DRILLING LOG | SHEET 3 OF 5 SHEETS

PROJECT: SAN PEDRO TUNNEL, SAN ANTONIO, TX.

HOLE NO.: 6A4C-305

DATE HOLE: STARTED 9 APRIL 86 | COMPLETED 16 APRIL 86

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS
	100.0			100.0		
		1		L:0.4	1	
		2		108.0	2	
			111.3-112.0' MECHANICAL BREAK	6'0 1'		
			114.0'-114.6' " " "	111.6		
		3		L'03	3	
	120				4	

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT)

PROJECT: SAN PEDRO TUNNEL | HOLE NO.: 6A4C-305

DL-223

Hole No. 6A4C-305

DRILLING LOG	DIVISION	INSTALLATION	SHEET 4 of 5 SHEETS

1. PROJECT: SAN PEDRO TUNNEL, San Antonio, Tx.
2. LOCATION (Coordinates or Station)
3. DRILLING AGENCY
4. HOLE NO. (As shown on drawing title and file number): 6A4C-305
5. NAME OF DRILLER
6. DIRECTION OF HOLE: ☐ VERTICAL ☐ INCLINED ____ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN
8. DEPTH DRILLED INTO ROCK
9. TOTAL DEPTH OF HOLE
10. SIZE AND TYPE OF BIT
11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
12. MANUFACTURER'S DESIGNATION OF DRILL
13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN | DISTURBED | UNDISTURBED
14. TOTAL NUMBER CORE BOXES
15. ELEVATION GROUND WATER
16. DATE HOLE: STARTED 9 APRIL 86 COMPLETED 16 APR 86
17. ELEVATION TOP OF HOLE
18. TOTAL CORE RECOVERY FOR BORING %
19. SIGNATURE OF INSPECTOR: Jackie R. [signature]

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
		4	121.8'-122.6': SCATTERED SMALL LENTICULAR GREENISH GRAY INCLUSIONS	121.0		
			125.0': PYRITE 125.7': " 126.0': "	L:0.1	5	
		5		127.1		
			132.0'-136.0': MOD-ERATELY SOFT-MOD-ERATELY HARD	G:0.1	6	
		6	136.4': MECHANICAL BREAK	137.0	7	
	140	7		L:0.0	8	
		8		146.5	9	
			150.0'-152.0': TRACE OF GREENSAND OR SEDIMENTARY SER-PENTINE 154.4'-155.1': MECHANICAL BREAK	G:0.2		
		9		155.5	10	
			157.1': PYRITE 157.7': "			
	160	10			11	

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT) | PROJECT: SAN PEDRO TUNNEL | HOLE NO.: 6A4C-305

DL-224

Hole No 6A4C-305

DRILLING LOG	DIVISION	INSTALLATION	SHEET 5 OF 5 SHEETS

1. PROJECT: SAN PEDRO TUNNEL, SAN ANTONIO, TX.
2. LOCATION (Coordinates or Station)
3. DRILLING AGENCY
4. HOLE NO. (As shown on drawing title and file number): 6A4C-305
5. NAME OF DRILLER
6. DIRECTION OF HOLE: ☐ VERTICAL ☐ INCLINED ____ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN
8. DEPTH DRILLED INTO ROCK
9. TOTAL DEPTH OF HOLE
10. SIZE AND TYPE OF BIT
11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
12. MANUFACTURER'S DESIGNATION OF DRILL
13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED | UNDISTURBED
14. TOTAL NUMBER CORE BOXES
15. ELEVATION GROUND WATER
16. DATE HOLE: STARTED 9 APRIL 86 | COMPLETED 16 APRIL 86
17. ELEVATION TOP OF HOLE
18. TOTAL CORE RECOVERY FOR BORING %
19. SIGNATURE OF INSPECTOR: Jackie R. Stallcup

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
				1.13		
					12	
	165.0		TD 165.0'	165.0		
	180					
	200					

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT)

PROJECT: SAN PEDRO TUNNEL | HOLE NO. 6A4C-305

DL-225

Hole No. 6D4C - 306

DRILLING LOG	DIVISION	INSTALLATION Fort Worth	SHEET 1 OF 1 SHEETS
1. PROJECT San Antonio, Texas		10. SIZE AND TYPE OF BIT 4" Shelby Tube/4" Core Barrel	
2. LOCATION San Pedro Creek Tunnel		11. DATUM FOR ELEVATION SHOWN	
3. DRILLING AGENCY Hamilton Drilling and Engineer Testing		12. MANUFACTURER'S DESIGNATION OF DRILL Denco 1250	
4. HOLE NO. 6D4C - 306		13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED 1, UNDISTURBED 6	
5. NAME OF DRILLER Duane Brothers		14. TOTAL NUMBER CORE BOXES 3	
6. DIRECTION OF HOLE: VERTICAL / INCLINED ___ DEG. FROM VERT.		15. ELEVATION GROUND WATER See comment 1	
7. THICKNESS OF OVERBURDEN 6.0		16. DATE HOLE: STARTED 18 April 86, COMPLETED 21 April 86	
8. DEPTH DRILLED INTO ROCK 25.0		17. ELEVATION TOP OF HOLE	
9. TOTAL DEPTH OF HOLE 31.0		18. TOTAL CORE RECOVERY FOR BORING 96 %	
		19. SIGNATURE OF INSPECTOR Randy Rutledge	

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS
			0.0' to 6.0' CLAY: 0.0' to 0.5': low-medium plasticity; gray; stiff; dry; silty; sandy; calcareous. 0.5' to 2.0': medium-high plasticity; brown; stiff; dry; silty; sandy gravelly; calcareous. 2.0' to 3.5': medium-high plasticity; yellow brown; medium stiff; moist; gravelly; sandy; calcareous. 3.5' to 6.0': high plasticity; yellow brown-gray; stiff; moist; some gypsum.		A, B, C, D, E	1. Water Level: Bailed the hole. The hole caved just below the bottom of the casing when the water was removed. 24 hr. check-water at 7.7' and caved below 10.1'.
	10		6.0' to 31.0' CLAY SHALE: 6.0' to 17.9' yellow brown; soft; weathered; silty; calcareous; numerous healed fractures; slightly fossiliferous	9.0 Run 1 L-0.0 11.1; 11.4 Run 3 L-0.0	Box 1	2. Jar Samples: A. 0.0 - 0.5; B. 0.5 - 2.0; C. 2.0 - 3.5; D. 3.5 - 6.0; E. 6.0 - 9.0; F. 14.4 - 14.6; G. 18.0 - 18.2; H. 22.8 - 23.0; I. 27.0 - 27.2
	20		17.9' to 18.8' brown-gray; moderately hard; silty; calcareous; some gypsum; weathered. 18.8' to 21.9' tan-brown (alternating zones); soft-moderately hard; silty; calcareous. 20.6 - 21.8 - vertical healed fracture.	19.0 Run 4 L-0.0; 23.0 Run 5 L-0.3	Box 2	3. Shelby Tube Pushes: 1. 0.0 - 1.5; 2. refusal; 3. 3.0 - 4.5; 4. 4.5 - 5.5; 5. 5.5 - 7.0; 6. 7.0 - 9.0. Jar samples of representative materials from the tube samples, with the rest of the sample discarded.
	0		21.9' to 31.0' gray; moderately hard; silty; calcareous. Unweathered. T.D. 31.0'	27.0 Run 6 L-0.6; 31.0	Box 3	4. Drilling Methods: 0.0 - 1.5 - 4" Shelby tube. 1.5 - 3.0 - 10" auger. 3.0 - 9.0 - 4" Shelby tube. Reamed the hole with a 10" auger to 8.0' and set 8' of 8" steel casing. Cleaned out the hole to 9.0' with 8" auger. 9.0 - 31.0 - 4" core barrel. Bailed the hole and pulled all of the casing. Grouted the hole with a bentonite/neat grout mix.

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT)

PROJECT San Pedro Creek Tunnel | HOLE NO. 6D4C - 306

DL-226

Hole No. 6D4C - 307

DRILLING LOG	Division SWD	Installation Fort Worth	Sheet 1 of 1 sheets

1. Project: San Antonio, Texas	10. Size and type of bit: 4" Shelby Tube/4" Core Barrel
2. Location (Coordinates or Station): San Pedro Creek Tunnel	11. Datum for elevation shown (TBM or MSL)
3. Drilling agency: Hamilton Drilling and Engineer Testing	12. Manufacturer's designation of drill: Damco 1250
4. Hole No. (As shown on drawing title and file number): 6D4C - 307	13. Total no. of overburden samples taken: Disturbed 4 / Undisturbed 1
5. Name of driller: Duane Brothers	14. Total number core boxes: 3
6. Direction of hole: [X] Vertical [ ] Inclined ___ Deg. from vert.	15. Elevation ground water: See comment 1
7. Thickness of overburden: 6.8	16. Date hole: Started 17 April 86; Completed 18 April 86
8. Depth drilled into rock: 21.2	17. Elevation top of hole
9. Total depth of hole: 28.0	18. Total core recovery for boring: 83 %
	19. Signature of inspector: Randy Fischer

Elevation a	Depth b	Legend c	Classification of Materials (Description) d	% Core Recovery e	Box or Sample No. f	Remarks (Drilling time, water loss, depth of weathering, etc., if significant) g
			0.0' to 6.4' CLAY: 0.0' to 1.5': medium-high plasticity; gray; stiff; slightly moist; silty; sandy; calcareous; trace of gravel. 1.5' to 5.5': medium-high plasticity; tan-brown; stiff; damp; silty; sandy; gravelly, very gravelly below 3.0' with clast sizes up to 3.5"; calcareous. 5.5' to 6.4': low plasticity; very light gray; medium stiff; moist; abundant lime nodules; silty.		A, B, C, D, E	1. Water Level: Bailed the hole. 48 hr. check - water at 6.8' and caved below 11.7'.
			6.4' to 6.8' SAND: tan; fine grained; medium dense; moist; some gravel.	10.0 Run 1 L-0.6 12.0	F	2. Jar Samples: A. 0.0 - 1.5; B. 1.5 - 5.5; C. 5.5 - 6.4; D. 6.4 - 6.8; E. 6.8 - 10.0; F. 14.0 - 14.2; G. 17.9 - 18.1; H. 27.6 - 27.0
	10		**6.8' to 28.0'** CLAY SHALE: 6.8' to 10.0': yellow brown-gray; soft; highly weathered; silty; calcareous; a few lime nodules and some lime powder. Numerous healed fractures.	Run 2 L-1.5 16.0 Run 3 L-0.0	BOX 1, G	3. Drilling Methods: 0.0 - 7.5 - 4" shelby tube. 7.5' to 10.0 - 8" auger. 10.0 - 16.0 - 4" core barrel. Reamed the hole to 16.0' with a 10" auger and placed 10' of 8" steel casing. Cleaned out the hole to 17.0' with an 8" auger. 17.0 to 28.0 - 4" core barrel. Bailed the hole and pulled all of the casing. Grouted the hole with a bentonite/cement grout mix after the water level was obtained.
	20		10.0' to 17.8': yellow brown; soft; weathered; silty; calcareous; calcareous. A few calcite filled fractures. From 10.0 - 10.7 - healed vertical fracture. Iron nodule at 16.6'.	22.0 Run 4 L-0.6	BOX 2	
	30		17.8' to 28.0': gray; soft-moderately hard; unweathered (Iron stained at 19.8'); silty; calcareous. T.D. 28.0'	24.0 Run 5 L-0.2 28.0	BOX 3, H	4. Shelby Tube Pushes: 1. 0.0 - 1.5; 2. 1.5 - 3.0; 3. 3.0 - 4.5; 4. 4.5 - 6.0; 5. 6.0 - 7.5. Representative jar samples of the materials were obtained, with the remainder of the materials discarded.

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT)

Project: San Pedro Creek Tunnel — Hole No. 6D4C - 307

DL-227

Hole No. 6D4C-308

DRILLING LOG	DIVISION: SWD	INSTALLATION: FWD	SHEET 1 OF 1 SHEETS

1. PROJECT: SAN PEDRO CREEK - UNIT 7-3-1	10. SIZE AND TYPE OF BIT: 4" CARBOLOY
2. LOCATION (Coordinates or Station): STA. 202+00	11. DATUM FOR ELEVATION SHOWN (TBM or MSL):
3. DRILLING AGENCY: USCE HAMILTON DRILLING	12. MANUFACTURER'S DESIGNATION OF DRILL: DAMCO 1250
4. HOLE NO. (As shown on drawing title and file number): 6D4C-308	13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: DISTURBED 4 / UNDISTURBED 0
5. NAME OF DRILLER: R BROTHERS	14. TOTAL NUMBER CORE BOXES: 3
6. DIRECTION OF HOLE: ☒ VERTICAL ☐ INCLINED ____ DEG. FROM VERT.	15. ELEVATION GROUND WATER: SEE REMARKS COLUMN
	16. DATE HOLE: STARTED 22 APRIL 86 / COMPLETED 23 APRIL 86
7. THICKNESS OF OVERBURDEN: 7.4'±	17. ELEVATION TOP OF HOLE:
8. DEPTH DRILLED INTO ROCK: 25.6'±	18. TOTAL CORE RECOVERY FOR BORING: 95 %
9. TOTAL DEPTH OF HOLE: 33.0'	19. SIGNATURE OF INSPECTOR: Jackie R. Stokes

ELEVATION (a)	DEPTH (b)	LEGEND (c)	CLASSIFICATION OF MATERIALS (Description) (d)	% CORE RECOVERY (e)	BOX OR SAMPLE NO. (f)	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) (g)
	0.0		0.0' To 1.7' CLAY: MEDIUM-HIGH PLASTICITY; DARK BROWN, HARD; DRY; CALCAREOUS, WITH SCATTERED L.S GRAVEL		A	1. WATER LEVEL: NOTE: NO FREE WATER IN OVER-BURDEN DURING DRILLING; BORING WAS BAILED TO 30.0 & LEFT OPEN
			1.7' To 3.0' GRAVEL: L.S. MEDIUM-LARGE; ANGULAR; MEDIUM; LIGHT BROWN; DRY, CLAYEY		B	24 HR OBSERVATION: FREE WATER LEVEL WAS AT 23.0
					C	
	7.4		3.0' To 7.4' CLAY: 3.0'-6.1': MEDIUM-HIGH PLASTICITY; DARK BROWN, HARD, DRY-DAMP; CALCAREOUS. 6.1'-7.4': MEDIUM PLASTICITY; LIGHT BROWN, HARD, DAMP; SILTY, CALCAREOUS	8.5	D	2. JAR SAMPLES: A: 0.0'-1.7'; B: 1.7'-3.0'; C: 3.0'-6.1; D: 6.1'-7.4'; E: 7.4-8.5'; F: 13.5; G: 18.5'; H: 23.5'; I: 28.5; J: 32.0'
				L: 0.0	E	
				13.0	1 "F"	
			7.4'± To 21.8'± CLAY SHALE: BADLY WEATHERED; YELLOWISH BROWN WITH LIGHT GRAY, SOFT; DAMP; HIGHLY FRACTURED WITH WELL HEALED FRACTURES, SLIGHTLY SILTY, CLAYEY; CALCAREOUS, MEDIUM-HIGH PLASTICITY, WITH FERRUGINOUS STAINS; CRACKS UPON EXPOSURE; BROKEN FROM 8.5-10.5'	L: 1.0		3. DRILLING: 10" FLIGHT AUGER: 0.0'-3.0'; 4" SHELBY TUBE: 3.0-7.5; NOTE: TUBES WERE EXTRUDED & JAR SAMPLES WERE TAKEN; NOTE: REAMED OUT WITH 10" AUGER & SET 8" CASING TO 7.5; 8" FLIGHT AUGER: 7.5'-8.5'; 4" CORE BARREL: 8.5'-33.0'
				18.0	"G"	
	20			L: 0.0	2	
				21.0	"H"	
				L: 0.0		
			21.8'± to 33.0' T.D. SHALE (MARL): UNWEATHERED; DARK GRAY (DRIES TO LIGHT BLUE GRAY); SOFT; DRY-DAMP, SILTY, CALCAREOUS; WITH NO FRACTURES OBSERVED IN CORE; CRACKS UPON EXPOSURE	26.0		
				L: 0.0	"I" 3	
				30.0		
				L: 0.0	"J"	
	33.0		T.D. 33.0'	33.0		
	40					

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT)

PROJECT: SAN PEDRO CREEK — HOLE NO. 6D4C-308

DL-237

Hole No. 4S4C-314

DRILLING LOG	DIVISION: SWD	INSTALLATION: FWD	SHEET 1 of 2 SHEETS

1. PROJECT	SAN PEDRO CREEK - UNIT 7-3-1
2. LOCATION (Coordinates or Station)	STA. 140 + 44
3. DRILLING AGENCY	USCE
4. HOLE NO. (As shown on drawing title and file number)	4S4C-314
5. NAME OF DRILLER	J. SUITS
6. DIRECTION OF HOLE	[x] VERTICAL [ ] INCLINED ___ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN	23.0' ±
8. DEPTH DRILLED INTO ROCK	31.5' ±
9. TOTAL DEPTH OF HOLE	54.5'
10. SIZE AND TYPE OF BIT	4" CARBOLOY
11. DATUM FOR ELEVATION SHOWN (TBM or MSL)	
12. MANUFACTURER'S DESIGNATION OF DRILL	FAILING 1500
13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN	DISTURBED: 9 / UNDISTURBED: 0
14. TOTAL NUMBER CORE BOXES	6
15. ELEVATION GROUND WATER	SEE REMARKS COLUMN
16. DATE HOLE	STARTED: 17 APRIL 86 / COMPLETED: 21 APRIL 86
17. ELEVATION TOP OF HOLE	
18. TOTAL CORE RECOVERY FOR BORING	99%
19. SIGNATURE OF INSPECTOR	Jackie R. [signature]

ELEVATION (a)	DEPTH (b)	LEGEND (c)	CLASSIFICATION OF MATERIALS (Description) (d)	% CORE RECOVERY (e)	BOX OR SAMPLE NO. (f)	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) (g)
	0.0		0.0' TO 9.2' CLAY FILL: 0.0'-0.5' MEDIUM PLASTICITY; BROWN; HARD, DRY-DAMP; GRAVELLY; CALCAREOUS. 0.5'-2.1' MEDIUM PLASTICITY; BROWN, HARD; DAMP; VERY GRAVELLY; CALCAREOUS, WITH WOOD DEBRIS. 2.1'-8.5' MEDIUM-HIGH PLASTICITY, DARK BROWN, HARD; DAMP, WITH CALCAREOUS NODULES & CARBON STAINS, WITH OCCASIONAL SMALL GRAVEL & WOOD DEBRIS. 8.5'-9.2' LOW-MEDIUM PLASTICITY; LIGHT BROWN-DARK BROWN, HARD; DAMP; CALCAREOUS; WITH LENSES OF SANDY SILT		A, B, C, D, E, F, G	1 WATER LEVEL: NOTE BORING WAS BAILED TO 51.0' & LEFT OPEN. 24 HR OBSERVATION: FREE WATER LEVEL WAS AT 14.2
			9.2' TO 19.0' ± CLAY: 9.2'-14.0' LOW-MEDIUM PLASTICITY, LIGHT BROWN-YELLOWISH BROWN; VERY STIFF TO MEDIUM-STIFF FROM 12.0; DAMP TO VERY MOIST FROM 12.0, GRAVELLY TO VERY GRAVELLY FROM 12.0, VERY CALCAREOUS; SILTY, WITH TRACE OF FINE SAND FROM 12.0'. 14.0-19.0' ± LOW PLASTICITY, LIGHT BROWN, MEDIUM; WET, VERY GRAVELLY; VERY CALCAREOUS, WITH TRACE OF SILT & SAND		H, BAG 1, I	2 JAR SAMPLES: A: 0.0' - 0.5'; B: 0.5' - 2.1'; C: 2.1' - 7.1'; D: 7.1' - 8.5'; E: 8.5' - 9.2'; F: 9.2' - 12.0'; G: 12.0' - 14.0'; H: 14.0' - 19.0'; I: 23.0' - 25.0'; J: 30.0'; K: 35.0; L: 40.0'; M. 45.0'; N: 47.5'; O: 54.2'
	20		19.0' ± TO 23.0' ± GRAVEL: GRADED; SPHERICAL NODULAR L.S. & CHERT; MEDIUM, SATURATED, VERY CLAYEY, CALCAREOUS, WITH TRACE OF FINE SAND; WITH SCATTERED COBBLES			3 BAG SAMPLES: B-1: 19.0'-23.0'
	23.0		23.0' ± TO 43.1' ± CLAY SHALE: BADLY WEATHERED; YELLOWISH BROWN WITH LIGHT GRAY, SOFT, DAMP, CLAYEY, CALCAREOUS, SLIGHTLY SILTY - SILTY, MEDIUM-HIGH PLASTICITY WITH FERRUGINOUS STAINING,	25.0, L: 0.5, 32.0, 6.0 2	1, 1, "J", 2, "K", 3, "L"	4 CARTON SAMPLES: NOTE: NO CARTON SAMPLES TAKEN. 5 DRILLING: 8" FLIGHT AUGER: 0.0' - 2.0; 4" SHELBY TUBE 2.0' - 13.0; NOTE: SHELBY REFUSAL AT 13.0; 8" FLIGHT AUGER: 13.0' - 24.0; NOTE: SET 6" STEEL CASING TO 24.0; 5" FLIGHT AUGER: 24.0 - 25.0'; 4" CORE BARREL: 25.0' - 54.5
	40					

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT) | PROJECT: SAN PEDRO CREEK | HOLE NO. 4S4C-314

DL-238

Hole No. 454C-314

DRILLING LOG	DIVISION	INSTALLATION	SHEET 2 OF 2 SHEETS

1. PROJECT: SAN PEDRO CREEK - UNIT 7-3-1	10. SIZE AND TYPE OF BIT
2. LOCATION (Coordinates or Station)	11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
3. DRILLING AGENCY	12. MANUFACTURER'S DESIGNATION OF DRILL
4. HOLE NO. (As shown on drawing title and file number): 454C-314	13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN — DISTURBED — UNDISTURBED
5. NAME OF DRILLER	14. TOTAL NUMBER CORE BOXES
6. DIRECTION OF HOLE: ☐ VERTICAL ☐ INCLINED ____ DEG. FROM VERT.	15. ELEVATION GROUND WATER
	16. DATE HOLE — STARTED: 17 APRIL 86 — COMPLETED: 21 APRIL 86
7. THICKNESS OF OVERBURDEN	17. ELEVATION TOP OF HOLE
8. DEPTH DRILLED INTO ROCK	18. TOTAL CORE RECOVERY FOR BORING %
9. TOTAL DEPTH OF HOLE	19. SIGNATURE OF INSPECTOR: [illegible signature]

ELEVATION (a)	DEPTH (b)	LEGEND (c)	CLASSIFICATION OF MATERIALS (Description) (d)	% CORE RECOVERY (e)	BOX OR SAMPLE NO. (f)	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) (g)
			WITH LIME POCKETS AT 27.8'; 29.1' & 29.7' CRACKS UPON EXPOSURE	40.5	4	
			43.1'± TO 54.5' T.D. SHALE: (MARL) UNWEATHERED; DARK GRAY (DRIES TO A LIGHT BLUISH GRAY; SOFT-MODERATELY SOFT; DRY-DAMP; CALCAREOUS; SILTY; WITH NO FRACTURES OBSERVED IN CORE	100	"M" 5 "N"	
			46.4'-47.7: SOFT; DAMP, WITH SANDY SILT LAMINATIONS	41.5		
				100	6	
	54.5		T.D. 54.5'	54.5	"O"	
	60					
	80					

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT)

PROJECT: SAN PEDRO CREEK — HOLE NO. 454C-314

DL-239

Hole No. 454C - 315

DRILLING LOG	DIVISION SWD	INSTALLATION FWD	SHEET 1 OF 2 SHEETS

1. PROJECT: SAN PEDRO CREEK - UNIT 7-3-1	10. SIZE AND TYPE OF BIT: 4" CARBOLOY
2. LOCATION (Coordinates or Station): STA. 142 + 10	11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
3. DRILLING AGENCY: USCE	12. MANUFACTURER'S DESIGNATION OF DRILL: FAILING 1500
4. HOLE NO. (As shown on drawing title and file number): 454C - 315	13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: DISTURBED 10, UNDISTURBED 0
5. NAME OF DRILLER: T SWITS	14. TOTAL NUMBER CORE BOXES: 5
6. DIRECTION OF HOLE: ☒ VERTICAL ☐ INCLINED ____ DEG. FROM VERT.	15. ELEVATION GROUND WATER: SEE REMARKS COLUMN
	16. DATE HOLE: STARTED 21 APRIL 86, COMPLETED 23 APRIL 86
7. THICKNESS OF OVERBURDEN: 28.2' ±	17. ELEVATION TOP OF HOLE
8. DEPTH DRILLED INTO ROCK: 20.8' ±	18. TOTAL CORE RECOVERY FOR BORING: 99 %
9. TOTAL DEPTH OF HOLE: 49.0'	19. SIGNATURE OF INSPECTOR: Jackie R. Stokes

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	0.0		0.0' TO 2.1' GRAVEL FILL: GRADED, L.S. MEDIUM; DRY; VERY CLAYEY; CALCAREOUS		A	1. WATER LEVEL: NOTE: BORING WAS BAILED TO 46.0 & LEFT OPEN
			2.1' TO 8.5' CLAY FILL: 2.1 - 4.2': MEDIUM-HIGH PLASTICITY; YELLOWISH BROWN WITH LIGHT GRAY; HARD; DAMP, CALCAREOUS		B	24 HR OBSERVATION: FREE WATER LEVEL WAS AT 16.3'
					C	
			4.2' - 8.5': MEDIUM-HIGH PLASTICITY; DARK GRAY & BROWN; HARD, DAMP; CALCAREOUS, WITH LIME NODULES, TRACE OF SAND & GRAVEL		D	2. JAR SAMPLES: A: 0.0 - 2.1 B: 2.1' - 4.2 C: 4.2 - 8.5 D: 8.5 - 9.0 E: 9.0 - 12.0 F: 12.0 - 13.1 G: 13.1' - 16.5 H: 16.5 - 18.8 I: 25.0 - 28.2 J: 28.2 - 29.0 K: 34.0 L: 39.0 M: 44.0 N: 48.8
					E	
			8.5' TO 16.5' CLAY: 8.5' - 12.0': MEDIUM PLASTICITY; GRAY; HARD; DAMP, SILTY; CALCAREOUS, LIGHT GRAY & SANDY FROM 9.0		F	
					G	
			12.0' - 13.1: MEDIUM PLASTICITY, LIGHT GRAY WITH YELLOWISH BROWN, VERY STIFF; DAMP; VERY CALCAREOUS, WITH LIME POCKETS, SLIGHTLY SILTY, GRAVELLY		H	
	20		13.1' - 16.5 MEDIUM-HIGH PLASTICITY, LIGHT GRAY & YELLOWISH BROWN, STIFF, VERY MOIST, GRAVELLY; VERY CALCAREOUS		BAG 1	3. BAG SAMPLES B-1: 18.8' - 25.0
						4. CARTON SAMPLES: NOTE: NO CARTON SAMPLES TAKEN
			16.5 TO 25.0 ± GRAVEL: MEDIUM-LARGE, ROUNDED; NODULAR L.S. & CHERT, MEDIUM; WET; VERY CLAYEY; VERY CALCAREOUS, WITH TRACE OF SILT & SAND		1	5. DRILLING: 8" FLIGHT AUGER: 0.0' - 3.0 4" SHELBY TUBE: 3.0' - 18.8 NOTE: SHELBY REFUSAL AT 18.8 8" FLIGHT AUGER: 18.8 - 29.0' NOTE: SET 6' STEEL CASING TO 29.0' 4" CORE BARREL: 29.0' - 49.0'
	28.2			29.0	J	
			25.0' ± TO 28.2' ± CLAY (REWORKED PRIMARY), MEDIUM-HIGH PLASTICITY, BROWN & YELLOWISH BROWN; VERY STIFF, DAMP; CALCAREOUS, GRAVELLY		1	
				L: 1.0	"K"	
			28.2 ± TO 38.5' CLAY SHALE: BADLY WEATHERED; YELLOWISH BROWN WITH LIGHT GRAY; SOFT; DAMP; CALCAREOUS; MEDIUM-HIGH PLASTICITY; CLAYEY; GUMMY, HIGHLY FRACTURED		2	NOTE: SHELBY SAMPLES WERE EXTRUDED & REPRESENTATIVE JAR SAMPLES WERE TAKEN
				38.0	"L"	
	40					

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT)

PROJECT: SAN PEDRO CREEK | HOLE NO.: 454C-315

DL-240

Hole No. 4SAC-315

DRILLING LOG	DIVISION	INSTALLATION	SHEET 2 OF 2 SHEETS
1. PROJECT: SAN PEDRO CREEK - UNIT 7-3-1		10. SIZE AND TYPE OF BIT	
2. LOCATION (Coordinates or Station)		11. DATUM FOR ELEVATION SHOWN (TBM or MSL)	
3. DRILLING AGENCY		12. MANUFACTURER'S DESIGNATION OF DRILL	
4. HOLE NO. (As shown on drawing title and file number)		13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN	DISTURBED / UNDISTURBED
5. NAME OF DRILLER		14. TOTAL NUMBER CORE BOXES	
		15. ELEVATION GROUND WATER	
6. DIRECTION OF HOLE: ☐ VERTICAL ☐ INCLINED ___ DEG. FROM VERT.		16. DATE HOLE	STARTED 21 APRIL 86 / COMPLETED 23 APRIL 86
		17. ELEVATION TOP OF HOLE	
7. THICKNESS OF OVERBURDEN		18. TOTAL CORE RECOVERY FOR BORING %	
8. DEPTH DRILLED INTO ROCK		19. SIGNATURE OF INSPECTOR: Jackie R. Stokes	
9. TOTAL DEPTH OF HOLE			

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
			WITH WELL HEALED FRACTURES & NO OPEN FRACTURES, SLIGHTLY SILTY; WITH FERRUGINOUS STAINING; CRACKS UPON EXPOSURE	G:0.2	3	
					"M"	
			38.5' TO 49.0' TD	45.0	4	
			SHALE (MARL), UNWEATHERED, DARK GRAY (DRIES TO A LIGHT BLUISH GRAY; SOFT-MODERATELY SOFT, DRY-DAMP, VERY CALCAREOUS, SILTY; WITH NO FRACTURES OBSERVED IN CORE, MODERATELY SOFT & VERY LIMY FROM 45.6-49.0	G:0.6		
	49.0			49.0	5 "N"	
			TD 49.0			
	60					
	80					

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT)

PROJECT: SAN PEDRO CREEK | HOLE NO. 4SAC-315

APPENDIX G

Geotechnical Instrumentation Report

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FINAL INSTRUMENTATION REPORT
FOR THE SAN PEDRO CREEK TUNNEL AND OUTLET SHAFT

SAN ANTONIO RIVER AND SAN PEDRO CREEK TUNNELS PROJECT
SAN ANTONIO, TEXAS

1.0 INTRODUCTION AND AUTHORIZATION

The San Antonio River and San Pedro Creek tunnels and associated shafts are currently being constructed by Ohbayashi Corporation (Ohbayashi) under the Phase II contract of the San Antonio Channel Improvements Project. Phase II design and construction contract administration are being performed by the U. S. Army Corps of Engineers (COE). Local sponsors of the project are the San Antonio River Authority (SARA) and the City of San Antonio, Texas.

The San Pedro Creek Tunnel (SPCT) is approximately 6,000 ft long. It extends from a 24-ft finished diameter inlet shaft located in the San Pedro Creek channel near Quincy Street to a 35-ft finished diameter outlet shaft located on the west bank of the San Pedro Creek channel at Guadalupe Street. The tunnel was excavated from the outlet shaft to the inlet shaft with a tunnel boring machine (TBM), and it has a "one-pass" lining of precast concrete segments. It has an approximate 27-ft excavated diameter and a 24-ft 4-inch finished diameter.

The San Antonio River Tunnel (SART) is approximately 16,000 ft long. It extends from a 24-ft finished diameter inlet shaft located near U. S. Highway 281 (McAllister Freeway) at Brackenridge Park to a 35-ft finished diameter outlet shaft located in a bend of the San Antonio River near Roosevelt Park.

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The SART is currently under construction, and it is planned to be lined with precast concrete segments. When completed, it will also have a 24-ft 4-inch finished diameter.

The SPCT and the SART were designed to bypass floodwaters beneath the City of San Antonio, Texas. Figure 1 shows the SPCT and SART plan alignments through the city, and Figure 2 shows the tunnel profiles.

Woodward-Clyde Consultants (WCC) had a subcontract with Ohbayashi to provide specified geotechnical instrumentation services during construction of the Phase II tunnels and shafts. The purpose of the instrumentation program was to obtain data that would be used by Ohbayashi and the COF for design verification and future design applications.

This report on the instrumentation installed in the SPCT and outlet shaft has been prepared in accordance with Section 2C, Paragraph 2.3(11) of the project specifications, and COE Letter CW-0896, dated 17 November 1989. It is organized into two volumes: Volume I contains the text, tables, and figures of the report, and Volume II contains the report appendices.

Following this introductory Section 1.0, Section 2.0 describes the types of instruments installed, and Section 3.0 discusses the instrumentation locations and installation procedures. Section 4.0 presents the instrumentation data and Section 5.0 provides summary interpretations of the data.

The appendices contained in Volume II are as follows:

Appendix A: Manufacturer's Brochures for Selected Instrumentation

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Appendix B: Results of Pull-Tests Performed on Instrumented Non-Structural Rock Bolts

Appendix C: Records of Data from Borescope Observations and Measurements

Appendix D: Tabulations of Raw and Reduced Instrumentation Data

Appendix E: Plots of Reduced Instrumentation Data

2.0 TYPES OF INSTRUMENTATION

Instrumentation installed for the SPCT and outlet shaft consists of multi-position borehole extensometers, rock bolt load cells, total pressure cells, reinforced concrete strain meters, convergence reference points, and displacement markers. In addition, as part of the tunnel instrumentation program, borescope observations were made in borings drilled for that purpose in the rock mass surrounding the SPCT excavation.

With the exception of the displacement markers and the borescope, all of the instrumentation installed for the SPCT and outlet shaft was supplied by Geokon, Inc. (Geokon), of Lebanon, New Hampshire. Copies of Geokon's brochures describing the instruments that were installed are contained in Appendix A. The displacement markers were procured from Alamo Iron Works in San Antonio, Texas, and the borescope was purchased from Hocker Inc., of Houston, Texas. Summary listings of instrument types and installation locations are provided in Tables 1 and 2. The following paragraphs briefly describe the different types of instruments.

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2.1 Multi-position Borehole Extensometers

Multi-position borehole extensometers are used to monitor ground deformations at different distances (positions) from an assumed fixed reference position. For the SPCT project, six-position borehole extensometers were used to monitor vertical deformations of the rock mass overlying the tunnel, and three-position borehole extensometers were used to monitor horizontal deformations of the rock mass surrounding the outlet shaft.

The borehole extensometers that were installed in the SPCT and outlet shaft were Geokon's model A-3-1500 borehole extensometers (see Appendix A). These are tensioned rod-type extensometers with groutable anchors. The reference heads are equipped with linear potentiometers for electronic monitoring of the anchor movements. The movements were also occasionally manually monitored using a digital depth micrometer. The potentiometers had a range of 4 inches, and the electrical read-out box provided a resolution of 0.001 inch. The resolution of the digital depth micrometer was also 0.001 inches, but the readings were only accurate to within about 0.005 inches under the most favorable monitoring conditions.

2.2 Rock Bolt Load Cells

The load cells installed for the SPCT project were "donut"-shaped, or hollow-centered, for installation on the ends of non-structural rock bolts. The load cells utilized for the project were Geokon's model 4900-50-1.0 50-ton capacity vibrating wire load cells (see Appendix A). The sensing element of these load

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cells consisted of four vibrating wire strain gages. Load development measured by the load cells was monitored electronically.

2.3 Total Pressure Cells

Total pressure cells were installed on the outside of selected precast concrete liner segments for monitoring the development of stresses in the segments as a result of rock mass loadings. They were also cast into the final concrete liner of the outlet shaft to monitor stresses developing in the liner. The pressure cells utilized for the SPCT project were Geokon's model 4800E total pressure cells (see Appendix A). These cells consisted of two circular stainless steel plates welded together at their periphery, and spaced apart by a narrow cavity filled with an antifreeze solution. Pressures acting on a cell forces the fluid against a diaphragm, which acts against a vibrating wire pressure transducer that converts the pressure to an electrical signal.

2.4 Reinforced Concrete Strain Meters

Reinforced concrete strain meters were embedded in selected precast concrete liner segments to measure the stresses developing in the reinforcing steel of the segments. The strain meters used were Geokon's model 4911 "Sister Bars" (see Appendix A). These instruments were essentially vibrating wire strain gages fixed to short lengths of reinforcing steel. For installation, the instruments were tie-wired to the reinforcing steel "cage" of the selected liner segments.

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2.5 Convergence Reference Points

Convergence reference points function as the end points for tape extensometer readings. The tape extensometer readings were used to monitor changes in chord lengths inside the tunnel, and hence, closure and deformation of the tunnel section. For the SPCT project, stainless steel eye-bolts attached to groutable rebar anchors were used for the reference points, and the tape extensometer was Geokon's model 1600-1 tape extensometer (see Appendix A). The tape extensometer had a resolution of 0.001 inch, and the readings were repeatable to 0.005 inch.

2.6 Surface Displacement Markers

Surface displacement markers were installed along the SPCT alignment to monitor the amount of surface displacement, if any, due to tunnel construction approximately 120 ft below the ground surface. The specified surface displacement markers consisted of 4-ft long lengths of No. 6 reinforcing steel driven vertically into the ground, with the top of the rod flush with the ground surface. The elevations of the tops of the rods were monitored using optical surveying techniques. Measurements were made to the nearest 0.001 ft, and the readings were considered accurate to 0.01 ft.

2.7 Borescope Observations

An Instrument Technology, Inc. model 122500 battery-powered extendable borescope was procured for the SPCT instrumentation program. It was fitted with a right-angle viewing head that

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provided a 2-inch relatively undistorted field of view, and an attachment was available for mounting a 35 mm camera at the viewing end. The eye-piece was inscribed with 0.025 inch graduations.

The borescope was used to observe, photograph, and measure fracture openings, including joints and bedding planes, in the rock mass surrounding the tunnel excavation. The observations and measurements were made in seven 8-ft long 3-inch diameter boreholes drilled at various angles from the inside of the TBM at approximately equal spacing, excluding the invert, around the periphery of the tunnel at COE-specified tunnel stations. Centering devices were attached to the borescope to keep it aligned in the boreholes.

3.0 INSTRUMENTATION LOCATIONS AND INSTALLATION PROCEDURES

Tables 1 and 2 list the instrumentation that has been installed in the SPCT and outlet shaft, including the quantities installed, the installation locations, and the dates of installation and latest readings. Table 2 also shows the status of the different instruments as of the dates of the latest readings. Figure ** shows the instrumentation locations relative to the SPCT alignment, and Figures ** through ** are schematic sketches of typical instrumentation installations.

The following paragraphs provide selected details of the instrumentation installation procedures. Except as noted, the instrumentation installations generally conformed with the project plans and specifications.

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3.1 Outlet Shaft Instrumentation

Instrumentation installed in the SPCT outlet shaft consists of 12 three-position borehole extensometers, 12 rock bolt load cells, and six total pressure cells. Four extensometers were installed at each of three elevations, namely approximate elevations 604 ft, 575 ft, and 550 ft (Project Datum, PD), four rock bolt load cells were installed at each of approximate elevations 596 ft, 575 ft, and 550 ft PD, and the six total pressure cells were installed at approximate elevation 562 ft PD. The installation configurations of the outlet shaft instruments are shown on Figures ** and **, and the installation procedures are discussed in the following paragraphs.

3.1.1 Borehole Extensometers. Figure ** shows a typical borehole extensometer installation in the outlet shaft. The extensometer anchors were at depths of approximately 3 ft, 11 ft, and 26 ft from the shaft wall. The reference head was recessed 24 inches in the wall to protect it from damage.

At each of the three instrumentation elevations, the electrical read-out cables from all four extensometers were routed along the circumference of the shaft through PVC conduit to a common point, where they were spliced to a multi-pair junction cable. The junction cable was then routed vertically through PVC conduit to the ground surface, where it terminates in a lockable watertight terminal box. At the time of this writing, the location of the extensometer terminal boxes is considered temporary; however, each terminal box is labeled, and identification for future monitoring is not expected to be problematical.

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Complete installation of four extensometers at one elevation was generally a two- to three-day effort, including time to drill the boreholes. After a borehole was drilled, the extensometer rods and standpipe were inserted, and a cement-based grout was pumped through the standpipe into the borehole. The grout was given 12 hours to cure, at which time the rods were tensioned and the reference head was installed. Electronic readings were typically erratic up to 24 hours after grout placement, but manual readings were taken immediately following installation.

3.1.2 Rock Bolt Load Cells. Figure ** shows a typical rock bolt load cell installation in the outlet shaft. The load cells were installed on 39-ft long No. 8 steel reinforcing bars, 19 ft of which were anchored with a 2-part fast-setting resin grout. The 20-ft long free length was double-wrapped with asphaltic tape and cased with 2-inch diameter PVC pipe to mitigate any anchoring effects that might occur on the free length as a result of closure of the borehole. The rock bolts installed for purposes of load cell instrumentation were not considered to be structural members.

Following installation of the rock bolts, and prior to placing the load cells, the bolts were pull-tested for verification of anchor reliability. The pull-tests consisted of loading and unloading the bolts in 1-ton increments (or decrements) while monitoring bolt movements. The maximum load applied during the pull-tests was 10 tons. In all except one case, bolt anchorage appeared satisfactory, with the load-deformation behavior of the bolt installations being approximately linear. The exceptional case was a bolt installed at approximate elevation 596 ft, the anchorage of which appeared to fail at an approximate load of **

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tons. Appendix B contains the results of all of the pull-tests performed for the non-structural rock bolt installations in the SPCT outlet shaft.

The load cells were mounted on the rock bolts immediately following completion of the pull-tests. Each load cell was seated on 1-inch thick steel bearing plate, and was held in place by a washer and nut assembly. In some cases, dry-pack (hydraulic) concrete was placed beneath the bearing plate, between the plate and the underlying rock mass, to improve the contact between the bearing plate and the rock mass, and to orient the bearing plate as nearly perpendicular to the bolt as possible. The end of the rock bolt was recessed approximately 6 inches in the shaft wall to protect the load cell from damage. There were no loads applied to the load cell at the time of installation other than the "snugging" load applied by the washer and nut assembly.

At each of the three instrumentation elevations, the electrical read-out cables from all four rock bolt load cells were routed to the ground surface in the same manner as the cables for the three-position borehole extensometers.

Complete installation of four rock bolt load cells at one elevation was generally a one- to two-day effort, including time to drill the boreholes and perform the pull-tests. After a borehole was drilled, the resin grout cartridges and the bolt were inserted into the borehole, and the bolt was spun to mix the cartridge ingredients. Approximately 15 minutes later, the bolt was pull-tested. The load cell was installed after completion of the pull-test. Electronic readings were typically erratic up to about 12 hours after load cell installation.

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The installation procedure for the instrumented rock bolts described herein represents a significant deviation from the project plans and specifications. As installed, the rock bolts have approximately 19-ft long by 1-5/8-inch diameter resin-encapsulated anchors instead of the specified 10-ft long by 3-inch diameter resin-encapsulated anchors. This change was necessary because the specifications were inconsistent with industry standard products and procedures.

3.1.3 **Total Pressure Cells**. Figure ** shows a typical total pressure cell installation in the outlet shaft. The pressure cells were attached with tie wires to reinforcing bars, then cast in the final concrete shaft liner.

Approximately 28 days after the pressure cells were installed, the cells were "repressurized" using a crimping tube mechanism designed for that purpose. Repressurization causes the cells to expand against the surrounding the concrete, and thereby fill any voids between the cells and the concrete resulting from contraction of the concrete as it cured.

The electrical read-out cables from all six total pressure cells were routed along the circumference of the shaft to a common point, then routed to the ground surface in a tied bundle. At the time of this writing, the cables terminated at individual spools temporarily located near the collar of the shaft. Within the shaft, the cables were cast in the final concrete shaft liner.

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3.2 Tunnel Instrumentation

Instrumentation was installed at two stations of the SPCT, namely Station 143+75 and Station 158+47. The instrumentation that was installed at each station consisted of the following:

- o One six-position borehole extensometer;
- o One rock bolt load cell;
- o Three total pressure cells;
- o Three reinforced concrete strain meters; and
- o Six convergence reference points.

In addition, borescope observations, photographs, and measurements were made at both instrumentation stations, and surface displacement markers were installed in the vicinity of Station 143+75.

The six-position borehole extensometers and the displacement markers were installed at least 200 ft in advance of the TBM excavation. The total pressure cells and the reinforced concrete strain meters were installed with the precast concrete liner segments, approximately 67 ft behind the TBM cutter head, and the rock bolt load cells were installed and the borescope observations made immediately after installation of the instrumented segments. The convergence reference points were installed as soon as practicable after installation of the precast segments, but it was not possible to make tape extensometer measurements until the TBM trailing gear had passed the instrumentation station, approximately 400 ft behind the cutter head.

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The installation configurations of the tunnel instruments are shown on Figures ** and **, and the installation procedures are discussed in the following paragraphs.

3.2.1 **Borehole Extensometers**. Figure ** shows a typical six-position borehole extensometer installation at a tunnel instrumentation station. The deepest extensometer anchor was located approximately 3 ft above the crown of the tunnel excavation, or approximately 115 ft below the ground surface, and the other 5 anchors were spaced between the deepest anchor and the weathered/unweathered shale interface. The reference head was located at the ground surface, but recessed approximately 3 ft so that its protective cover was installed flush with the surface.

The electrical read-out cable from the extensometer was routed through conduit to a watertight terminal box. For the extensometer at Station 143+75, the terminal box was temporarily located in a lockable utility shed placed on the project site for that purpose. For the extensometer at Station 153+47, the terminal box was placed in a recessed lockable rectangular valve box installed near the extensometer.

Complete installation of a six-position borehole extensometer was generally a four- to five-day effort. On the first day, 12-inch diameter PVC casing was drilled through the overburden soils and weathered shale at the extensometer location, and grouted in place. Approximately 12 hours later, after the grout had set, the boring was advanced through the unweathered shale to total depth. Rock cores were recovered from the boring, and logged for geologic characteristics. After the borehole was drilled, the extensometer rods and standpipe were inserted, and a cement-based grout was pumped through the standpipe into the

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borehole. The grout cured at least 24 hours, at which time the rods were tensioned and the reference head was installed. Electronic readings were typically erratic up to 24 hours after grout was placed, but manual readings were taken immediately following installation.

3.2.2 Rock Bolt Load Cells. The rock bolt load cell installations varied between the two SPCT instrumentation stations. Therefore, the installations will be discussed separately.

(a) Instrumentation Station 143+75. Figure ** shows the rock bolt load cell installation at Station 143+75 of the SPCT. It is similar to the load cell installations in the outlet shaft. The rock bolt was installed vertically in the roof of the tunnel from the top of the TBM main beam through a 12-inch diameter "block-out" that had been cast for that purpose in the liner segment. The bolt was installed vertically rather than radially because the configuration of the TBM machinery did not accommodate a radial drill rig set-up in the roof of the tunnel. The vertical installation took a significantly longer period of time than the horizontal installations in the outlet shaft due to difficulties experienced in placing the resin grout cartridges in the borehole. Grout dripped from the borehole after it was mixed until sufficient time had passed for it to completely set.

Following installation, and prior to mounting the load cell, the rock bolt was pull-tested in the manner described previously for the bolts installed in the outlet shaft. The maximum load applied during the pull-test was 8.5 tons. Although the bolt anchorage appeared to slip at an approximate 5-ton load, it

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successfully held the maximum 8.5-ton load. Appendix B contains the results of the pull-test performed for the bolt installed at Station 143+75.

The load cell was mounted on the rock bolt immediately following completion of the pull-test in the manner described previously for the bolts installed in the outlet shaft. The load cell installation was recessed in the block-out cast in the 12-inch thick precast liner segment. The instrumented rock bolt was stressed with an approximate 1-ton tensile load at the time of installation.

The electrical read-out cable for the load cell was spliced to a junction cable that ran along the outer surface of the liner to the hydraulic instrumentation shaft located at approximate Station 143+00. The junction cable was then routed to the ground surface through the hydraulic instrumentation shaft to a watertight terminal box temporarily located in a lockable utility shed placed near the collar of the shaft for that purpose.

(b) Instrumentation Station 158+47. Partially due to the difficulty experienced at Station 143+75 in placing the resin grout cartridges, the decision was made to change to a cement-based grout anchorage for the rock bolt installation at Station 158+47. The anchor length was increased from 20 to 25 ft, and the grout cured for 90 hours before the bolt was pull-tested. However, in all other respects, the installation was the same as the Station 143+75 installation. The bolt was successfully pull-tested to a maximum load of 8 tons, and it was stressed with an approximate 1-ton tensile load at the time of installation. Appendix B contains the results of the pull-test performed for the bolt installed at Station 158+47.

The electrical read-out cable for the load cell was spliced to a junction cable that was routed to the ground surface through steel conduit attached to the inside wall of the ventilation shaft located at approximate Station 158+14. It was necessary to place the junction cable in a conduit to avoid damaging it when the ventilation shaft was subsequently used by Ohbayashi as a temporary pea gravel hopper. At the ground surface, the cable was routed through conduit to a terminal box located in the same recessed valve box previously described for the Station 158+47 six-position borehole extensometer.

3.2.3 Total Pressure Cells. Figure ** shows a typical total pressure cell installation on a precast concrete liner segment. The total pressure cells were epoxied in block-outs cast in the outer surface of the segments for that purpose.

At each instrumentation station, the electrical read-out cables from the pressure cells were routed around the outside of the segment ring to the crown of the tunnel where they were spliced to the same multi-pair junction cable as the rock bolt load cell. The terminal box for the total pressure cells installed at Station 143+00 was temporarily located in the lockable utility shed placed on the project site for that purpose, and the terminal box for the total pressure cells installed at Station 158+47 was located in the same enclosure as the terminal box for the six-position borehole extensometer.

3.2.4 Reinforced Concrete Strain Meters. Figure ** shows a typical reinforced concrete strain meter installation in a precast concrete liner segment. The reinforced concrete strain meters were embedded in the precast segments when the segments were manufactured.

At each instrumentation station, the electrical read-out cables from the strain meters were routed around the outside of the segment ring in the same manner as the total pressure cells, and spliced to the same junction cable as the rock bolt load cell and the pressure cell cables. The terminal boxes for the reinforced concrete strain meters are the same as for the total pressure cells. The terminal boxes have labeled switches for the different types of instrumentation, so future monitoring is not expected to be problematical.

3.2.5 <u>Convergence Reference Points</u>. Figure ** shows a typical convergence reference point installation in the SPCT. The reference points were not installed in the tunnel crown or invert because the presence of the ventilation duct in the roof and the muck train tracks in the invert made it impossible to access the points for monitoring and maintenance. A 2-part resin grout was used to anchor the reference points in holes drilled in the precast concrete liner segment for that purpose.

It was not possible to make the tape extensometer measurements within about 400 ft of the TBM cutter head because the tunnel section was blocked with the TBM trailing gear and transformer jumbo. After the TBM equipment had passed the station, access to the convergence points was only available with a "man-lift", use of which blocked passage of the muck trains.

3.2.6 <u>Surface Displacement Markers</u>. Figure ** shows the locations of the surface displacement markers installed along the SPCT alignment. The marker rods were hammered into place with a sledge. Surveys of the marker elevations were made when the markers were accessible; however, because the markers were

located in one of Ohbayashi's storage areas, they were frequently covered with stored equipment or materials, and hence, were inaccessible.

3.2.7 **Borescope Observations and Measurements**. Figure ** shows the locations and orientations of the boreholes drilled at COE-specified stations for the borescope observations and measurements. As indicated in the project plans and specifications, it was intended that the boreholes be drilled radially. However, the configuration of the TBM machinery did not accommodate a radial drill rig set-up in the tunnel at every boring location. The drill rig was mounted on the erector ring of the TBM.

Each boring was observed with four passes of the borescope, each pass being offset from the previous by 90 degrees. If a fracture was observed during any of the passes, its location in the boring was noted, its aperture was measured, and it was photographed. Appendix C contains the records of the borescope observations and measurements. It is noted that the borescope observations and measurements were made at only one time for each instrumentation station.

4.0 INSTRUMENTATION DATA

4.1 Monitoring Program

During construction of the SPCT and outlet shaft, an automatic data acquisition system (ADAS) was utilized to obtain electronic instrumentation data on a daily basis. However, the data were only reported to Ohbayashi and the COE when there were significant changes, but at least once a month. The data

reports consisted of tabulations of the raw and reduced data, and plots of the reduced data versus time elapsed since instrumentation installation. In general, data reports were submitted daily for 14 to 28 days following installation, weekly for the next 28 days, and monthly thereafter through November 1989.

The instrumentation that was not monitored with the ADAS included certain three-position borehole extensometers in the outlet shaft that had become electronically non-functional (see Table 2), the convergence reference points in the tunnel, and the displacement markers. When accessible, these instruments were monitored on a daily basis for 14 to 28 days following installation, weekly for the next 28 days, and monthly thereafter through November 1989.

Appendix D contains reports of the raw and reduced data obtained from the SPCT and outlet shaft instrumentation, and Appendix E contains plots of the reduced data vs. elapsed time since instrument installation. It is noted that some of the data presented in Appendices D and E have been edited to eliminate anomalous data from the data records, and hence, the records may differ from reports that have been previously submitted.

4.2 Summary of Data

The following paragraphs contain brief summaries of the SPCT and outlet shaft instrumentation data. The data are summarized on the basis of shaft elevation or tunnel station. Because the different types of instruments were designed for monitoring

different ground behavior parameters, the data summaries, and subsequent data interpretations (Section 5.0) focus on the trends of the data rather than on the actual data values.

4.2.1 Outlet Shaft.

(a) Elevation 604. The rock mass at approximate elevation 604 at the outlet shaft site was identified by the COE as weathered Taylor Shale. It had a soft consistency, and was damp to the touch.

Data from the borehole extensometers installed at approximate elevation 604 showed the somewhat unusual trend of initially increasing in value (indicating extension of the instrument rods, or closure of the shaft section), then decreasing for a net reading on the order of +/-0.01 inch. The maximum extension measured by the elevation 604 extensometers was +/-0.05 inch.

(b) Elevation 596. The rock mass at approximate elevation 596 was identified by the COE as unweathered Taylor Shale bedrock. In the SPCT outlet shaft, it was logged as being primarily soft to moderately soft, with some limy zones.

As with the extensometers installed at approximate elevation 604, data from the rock bolt load cells installed at approximate elevation 596 showed the unusual trend of initially increasing in value (indicating tensile loading of the bolt), then decreasing. However, data from the load cells installed at positions 1, 2, and 4 indicated subsequent reloading of the bolts. At the time of the last reading, the tensile loads acting on the position 2 and 4 bolts were continuing to increase with time, although at a decreasing rate.

The maximum loads measured by the rock bolt load cells installed at approximate elevation 596 were as follows:

Position	Total Load (kips tension)	Date of Reading
1	2.1	21 Nov. 1989
2	4.6	24 Aug. 1990
3	0.4	24 Aug. 1990
4	3.8	24 Aug. 1990

(c) **Elevation 575.** The majority of the displacements measured by the borehole extensometers installed at approximate elevation 575 occurred over a relatively short period of time, 20 to 30 days, followed by relatively minor to negligible additional displacements occurring over a long-term period. The maximum displacements measured by the borehole extensometers installed at approximate elevation 575 were as follows:

Position	Max. Displacement (inches extension)	Date of Reading
A	0.086	24 Oct. 1989
B	0.102	24 Aug. 1990
C	0.104	24 Aug. 1990
D	0.098	24 Aug. 1990

The trend of the elevation 575 rock bolt load cell data was similar to the trend of the elevation 575 extensometer data, namely, the majority of the measured load development occurred over a relatively short period of time, 20 to 30 days, followed by relatively minor additional load development occurring over a long-term period. As of the last reading of the load cell data, it appeared that the tensile loads were continuing to develop on all four bolts. The maximum measured loads were as follows:

Position	Total Load (kips tension)	Date of Reading
1	3.2	24 Aug. 1990
2	3.0	24 Aug. 1990
3	3.9	24 Aug. 1990
4	2.7	24 Aug. 1990

(d) Elevation 550. The trend of the data from the borehole extensometers installed at approximate elevation 550 was generally the same as the trend observed for the elevation 575 extensometer data. It is noted that the elevation 550 extensometer located at position A had been monitored manually. Therefore, there was more variation between consecutive data values than was observed for the extensometer data obtained electronically.

The maximum displacements measured by the borehole extensometers installed at approximate elevation 550 were as follows:

Position	Max. Displacement (inches extension)	Date of Reading
A	0.092	12 Oct. 1989
B	0.084	21 Nov. 1989
C	0.063	24 Aug. 1990
D	0.064	24 Aug. 1990

The trend of the data from three of the elevation 550 rock bolt load cells was similar to the trend observed for the elevation 575 load cells, with the exception that tensile load development appears to be continuing only for the position 3 bolt. The bolt at position 1 was disturbed by construction activities, and appeared to develop a compressive loading that the load cell installation was not designed to monitor.

The maximum bolt loads measured by the elevation 550 rock bolt load cells were as follows:

Position	Total Load (kips tension)	Date of Reading
1	Disturbed	24 Aug. 1990
2	2.9	24 Aug. 1990
3	4.7	24 Aug. 1990
4	3.0	24 Aug. 1990

4.1.2 Instrumentation Station 143+75.

(a) Six-Position Borehole Extensometer. Data from the six-position borehole extensometer installed at approximate Station 143+75 indicate that significant ground movements above the crown of the tunnel did not occur in response to the tunnel excavation until the TBM was directly below the instrument installation. Ground movements apparently continued to occur for the next approximately 50 days, at which time the TBM had advanced 443 feet beyond the instrument installation, which approximately coincides with the time at which Ohbayashi began placing pea gravel and grout in the annular space between the precast concrete liner segments and the surrounding rock mass.

Data from the six-position borehole extensometer installed at approximate Station 143+75 were anomalous in that the shallower anchors 2, 3, and 4 showed greater movements than the deeper anchor 5. Furthermore, gross movement of anchor 6 did not occur until the TBM had advanced 443 feet beyond the instrument installation.

Maximum relative movements measured by the six anchors of the borehole extensometer installed at approximate Station 143+75 were as follows:

Anchor	Max. Rel. Movement (inches extension)
1	0.0
2	0.081
3	0.105
4	0.137
5	0.029
6	0.555

(b) **Surface Displacement Markers.** Survey data for the surface displacement markers installed in the vicinity of Station 143+75 indicate ground surface movements ranging from about 0.028 inch "heave" to 0.040 inch "subsidence", with no apparent consistent trend and with no apparent relationship to tunneling operations.

(c) **Rock Bolt Load Cell.** Data from the rock bolt load cell installed at approximate Station 143+75 showed a reduction in load below the approximate 1-ton tensile pre-load. The most feasible explanation for these data are that the bolt anchor failed immediately upon instrumentation installation (if not sooner).

(d) **Total Pressure Cells and Reinforced Concrete Strain Meters.** The total pressure cells and reinforced concrete strain meters installed at approximate Station 143+75 had erratic readings until the annular space between the precast concrete liner segments and the surrounding rock mass was filled with pea gravel and the invert was grouted. After that time, the data indicate nearly symmetrical stress development in the arch segments of the tunnel lining. Furthermore, the trends of stress development appear nearly identical as measured by the

total pressure cells and the reinforced concrete strain meters, namely initially increasing to a maximum value, then decreasing. The maximum total pressure cell measurements were on the order of 40 to 60 psi, and the maximum reinforced concrete strain meter measurements were on the order of 3200 psi.

(e) Convergence Reference Points. The convergence reference points installed at approximate Station 143+75 were not monitored until the TBM cutter head had advanced approximately 1000 feet (in 76 days) beyond the instrumentation station. Nonetheless, the convergence measurements indicate that the precast concrete segmental tunnel lining deformed from circular, with the diameter at the springline increasing in length, and the diameters at the quarter-points decreasing in length. The maximum measured increase of the springline diameter was 0.21 inch, and the maximum measured decrease of the quarter-point diameter was 0.07 inch.

(f) Borescope Observations and Measurements. Very few fractures were observed with the borescope at Station 143+75, and all of the fracture observations were in borings located above the springline of the tunnel. The general orientation of the fractures appeared to be horizontal, and along bedding planes of the Taylor Shale. The observed apertures ranged from 0.02 inch to 1.6 inches wide (see Appendix C).

4.1.3 Instrumentation Station 158+47.

(a) Six-Position Borehole Extensometer. As at Station 143+75, data from the six-position borehole extensometer installed at approximate Station 158+47 indicate that significant ground movements above the crown of the tunnel did not occur in

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response to the tunnel excavation until the TBM was directly below the instrument installation. Ground movements apparently continued to occur for the next approximately 14 days, at which time the TBM had advanced 43 feet beyond the instrument installation, which approximately coincides with the time at which Ohbayashi began placing pea gravel in the annular space between the precast concrete liner segments and the surrounding rock mass.

Data from the six-position borehole extensometer installed at approximate Station 158+47 were anomalous in that the shallower anchors 3, 4 and 5 showed greater movements than the deeper anchor 6.

Maximum relative movements measured by the six anchors of the borehole extensometer installed at approximate Station 158+47 were as follows:

Anchor	Max. Rel. Movement (inches extension)
1	0.0
2	0.054
3	0.098
4	0.089
5	0.153
6	0.086

(b) Rock Bolt Load Cell. As with the rock bolt load cell installed at approximate Station 143+75, data from the rock bolt load cell installed at approximate Station 158+47 showed a reduction in load below the approximate 1-ton tensile pre-load. The most feasible explanation for these data are that the bolt anchor failed immediately upon instrumentation installation (if not sooner).

(c) Total Pressure Cells and Reinforced Concrete Strain Meters. The total pressure cells and reinforced concrete strain meters installed at approximate Station 158+47 had erratic readings until the annular space between the precast concrete liner segments and the surrounding rock mass was filled with pea gravel and the invert was grouted. After that time, the reinforced concrete strain meter data indicate nearly symmetrical stress development in the arch segments of the tunnel lining. Furthermore, the trends of stress development appear nearly identical as measured by the total pressure cells and the reinforced concrete strain meters.

The maximum total pressure cell measurement was 113 psi, and the maximum reinforced concrete strain meter measurements were on the order of 4500 psi.

(d) Convergence Reference Points. The convergence reference points installed at approximate Station 158+47 were not monitored until the TBM cutter head had advanced approximately 400 feet (in 20 days) beyond the instrumentation station. The convergence measurements indicate that the diameter of the precast concrete segmental tunnel lining increased at the springline and at the quarter-points. The maximum measured increase of the springline diameter was 0.13 inch, and the maximum measured increases of the quarter-point diameters were 0.04 inch and 0.12 inch.

(e) Borescope Observations and Measurements. Very few fractures were observed with the borescope at approximate Station 158+47, and all of the fracture observations except two were in borings located above the springline of the tunnel. The general orientation of the fractures appeared to be horizontal,

and along the bedding planes of the Taylor Shale. The observed apertures ranged from 0.025 inch to 1.5 inches wide (see Appendix C).

5.0 INTERPRETIVE GROUND PERFORMANCE

In general, as of the dates of the latest instrumentation readings, the instrumentation data have not indicated the development of any alarming trends in rock mass behavior that would threaten the integrity of the constructed San Pedro Creek Tunnel and outlet shaft. However, it is noted that some of the instrumentation data continue to show increasin deformations, loads, and stresses. It is anticipated that the rock mass surrounding the tunnel and shaft may undergo swelling deformation when exposed to water seeping through the lining during system operation, and thereby causee additional deformation or stress development in the tunnel and shaft linings.

The following specific conclusions are made relative to the behavior of the ground during excavation of the SPCT and outlet shaft, as indicated by the instrumentation data:

- The initial peaking and subsequent decrease of deformations and load development measured by the extensometers and rock bolt load cells installed at approximate elevations 604 and 596, respectively, in the outlet shaft may be accounted for by one, or a combination, of the following scenarios: 1) desiccation and shrinkage of the rock mass on which the .tensometer heads and the load cell bearing plates are

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bearing; 2) the rock mass surrounding the grouted anchors of these instruments has undergone creep at the depth of the instrumentation anchors, or the anchors have failed; and/or 3) a transfer of rock loads to the shotcrete lining of the shaft. In the case of potential scenarios (1) and (2), the distance between the anchors and the extensometer head or the load cell would decrease, and the instrumentation measurements would decrease. In the case of potential scenario (3), the later increase in loads developing in the rock bolts may then be indicating that the shotcrete lining became loaded and began acting as a compression ring. Data from strain gages installed per Ohbayashi on one ring beam in the shaft excavation indicate that most stress development in the beam occurred within 120 days of placement of the beam.

- The instrumented rock bolt installations are not compatible with either the shaft construction support system or the tunnel lining system. Therefore, the stresses calculated as being either bolt stresses or rock mass stresses are not considered to be representative of the stresses developing in the shaft and tunnel linings. However, the trend of the stress development in the bolts may be indicative of the development of stresses in the linings; that is, the ongoing bolt stress development being measured by 10 of the 12 rock bolt load cell installations in the shaft may indicate continuing stress development in the shaft lining.

- The three-position borehole extensometer measurements in the shaft appear to indicate that rock mass deformations are relatively uniform in a two-dimensional horizontal plane at a give elevation. At the time of this writing, the maximum decrease in shaft diameter indicated by the

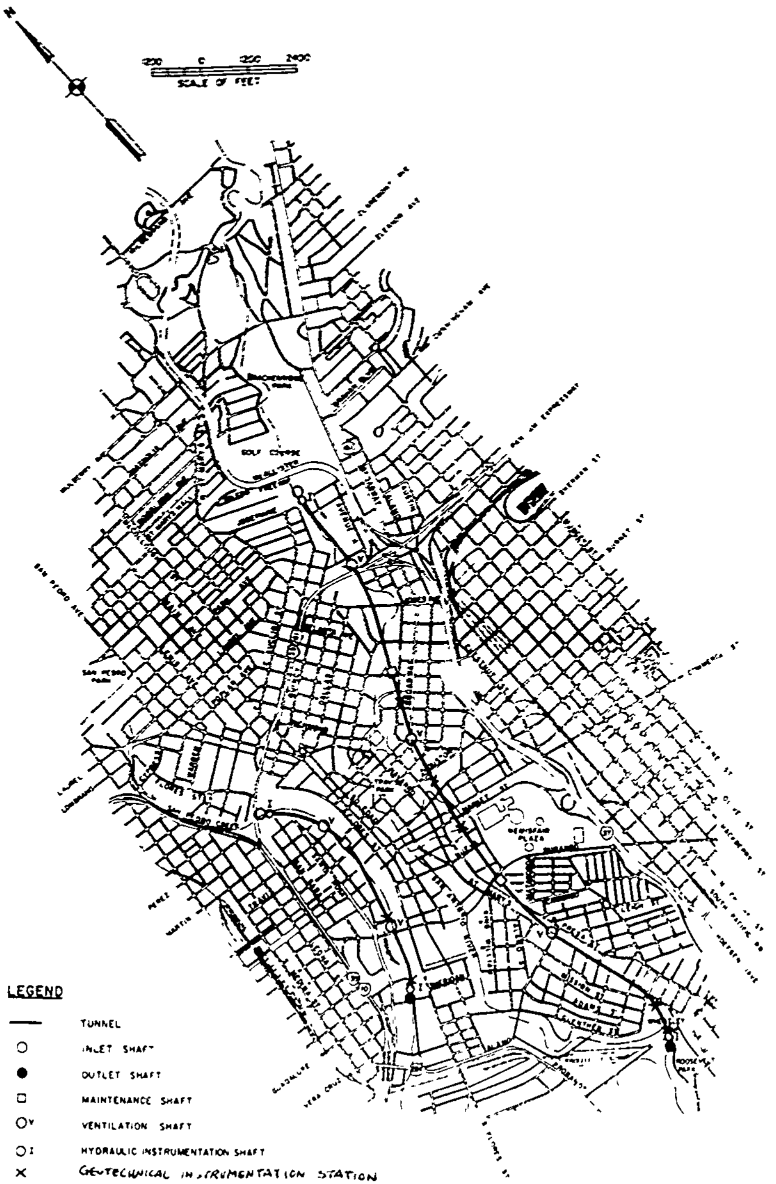
extensometer measurements is on the order of 0.15 to 0.2 inch. However, six of the 12 extensometer installations indicate that shaft rock wall movements are continuing to occur, which trend is consistent with the trend of the data from some of the rock bolt load cell installations in the shaft.

- Data from the reinforced concrete strain meters installed at approximate Stations 143+75 and 158+47 in the tunnel indicate a relatively uniform pressure developing in the arch segments of the tunnel lining at these stations on the order of 25 psi. Data from the total pressure cells installed at the same stations indicate relatively uniform pressures developing in the arch segments ofon the tunnel lining on the order of 15 psi and 40 psi, respectively.

- There appears to be a good correlation between the trends of lining stress development as indicated by the total pressure cell and the reinforced concrete strain meter measurements at approximate Station 143+75 and Station 158+47. However, during the course of construction, the magnitudes of the stresses indicated by the total pressure cell measurements indicated significantly greater radial pressure on the tunnel lining than did the reinforced concrete strain meter measurements. This difference may reflect the greater sensitivity of the total pressure cell measurements to relatively localized tunnel lining deformations than the reinforced concrete strain gage measurements. Such localized tunnel lining deformations could have been caused by the loads of the mining equipment operating inside the tunnel and/or differential confinement of the liner segments by the in situ rock and/or the pea gravel and grout backfill.

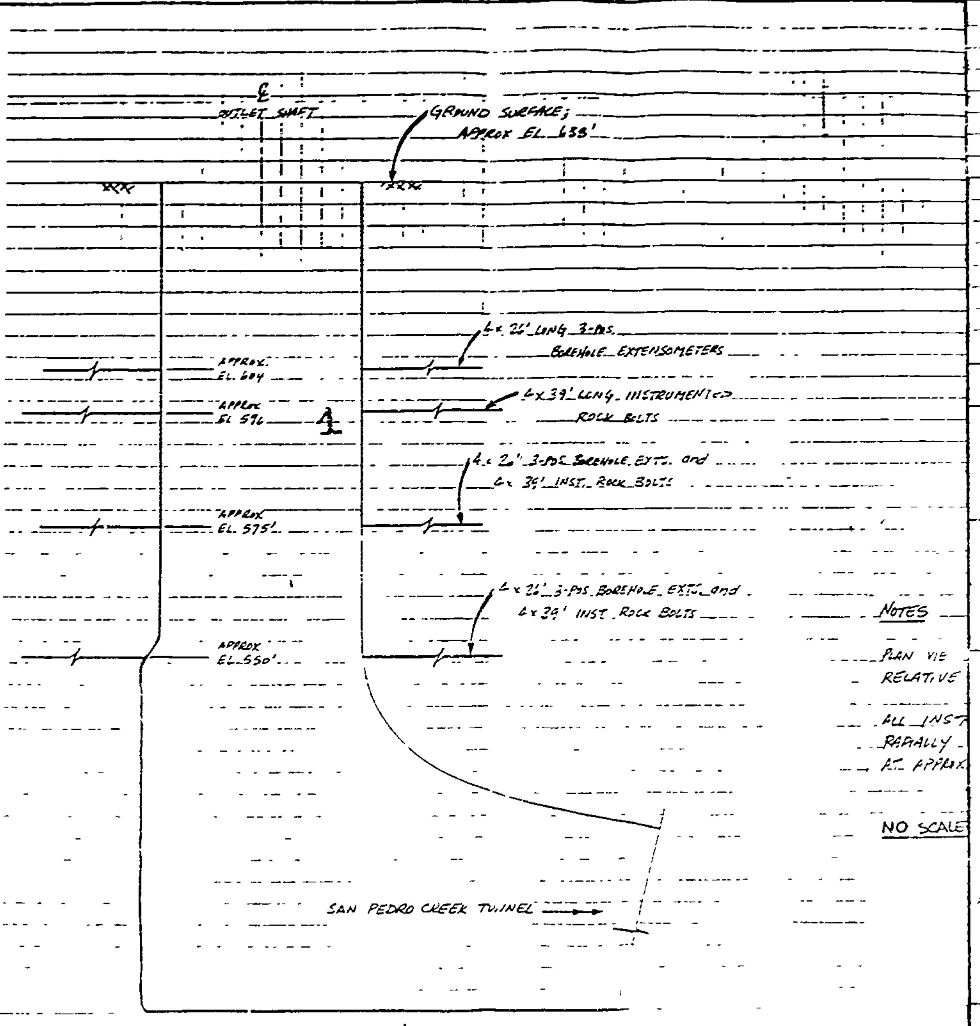
- A comparison of data from the six-position borehole extensometers installed at approximate Stations 143+75 and 158+47 along the tunnel alignment with survey data from the surface displacement markers installed between Stations 143+00 and 145+00 indicates that rock mass settlements above the tunnel excavation attenuate with distance above the excavation to become practically negligible at the ground surface. It is considered that the survey data from the surface displacement markers are related to surface activities in Ohbayashi's storage area, for which there are no accurate records, and/or apparent shrink and swell activity of the overburden soils in the vicinity of Station 143+75. These effects appear to be sufficient to mask excavation-induced ground surface settlements.

- There does not appear to be a correlation between the borescope observations of fracture frequency and orientation and other instrumentation data or observed rock mass behavior. The relatively few fractures observed with the borescope in the vicinity of Stations 143+75 and 158+47 of the tunnel would indicate that less rock mass movement should be anticipated above the tunnel excavation than was actually measured by the six-position borehole extensometers installed to within 3 ft of the tunnel crown. This finding may be due to the relatively short period of time from tunnel advance to borescope observations compared to the months-long period of time over which the extensometer data were obtained. Furthermore, the borescope observations were made through the shield of the TBM whereas most of the ground movements measured by the extensometers occurred after the shield had been advanced beyond the instrumentation station.

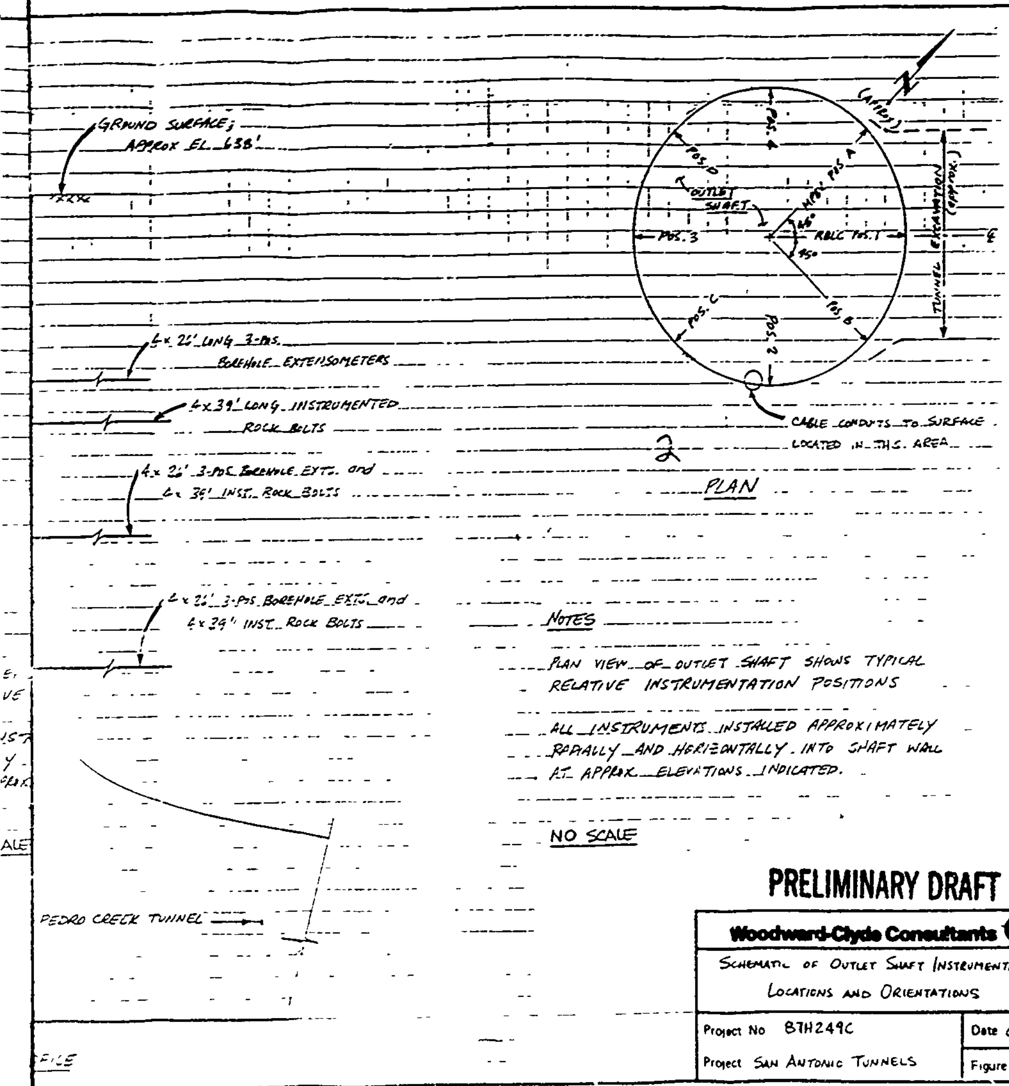


PROJECT TUNNEL ALIGNMENT AND INSTRUMENTATION STATIONS

Project No 87H249C	Date 01/31/90	Project SAN ANTONIO TUNNELS	Fig 1



SHAFT PROFILE



NOTES

PLAN VIEW OF OUTLET SHAFT SHOWS TYPICAL RELATIVE INSTRUMENTATION POSITIONS

ALL INSTRUMENTS INSTALLED APPROXIMATELY RADIALLY AND HORIZONTALLY INTO SHAFT WALL AT APPROX. ELEVATIONS INDICATED.

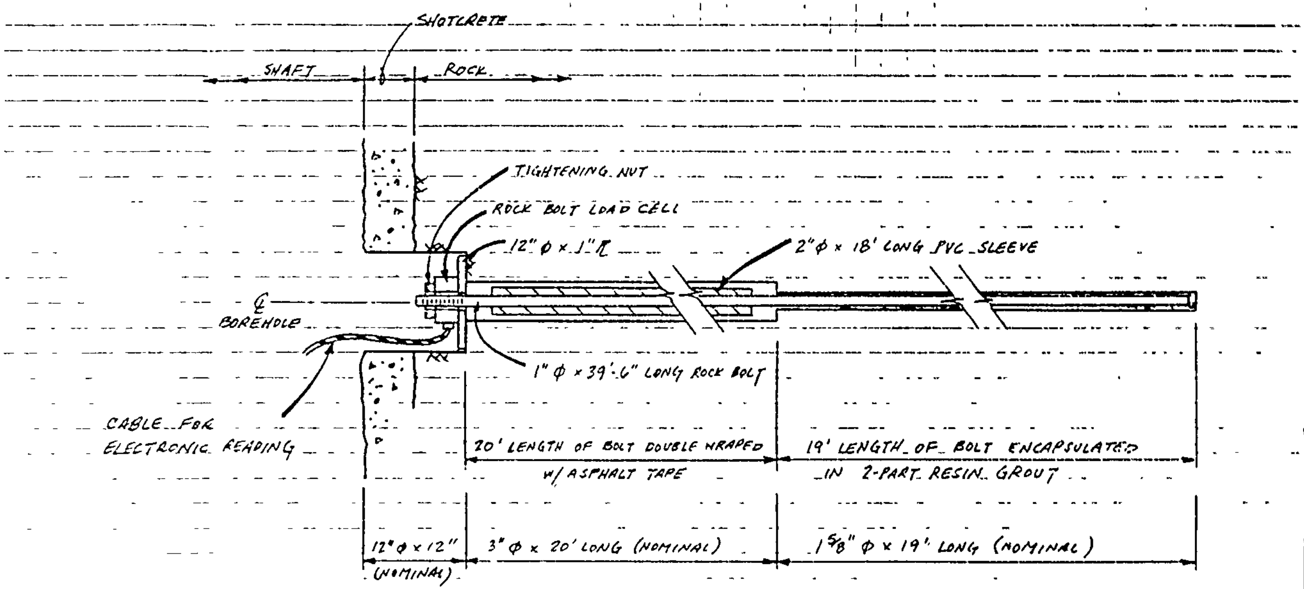
NO SCALE

PRELIMINARY DRAFT

Woodward-Clyde Consultants

SCHEMATIC OF OUTLET SHAFT INSTRUMENTATION LOCATIONS AND ORIENTATIONS

Project No 87H249C	Date 01/31/90
Project SAN ANTONIO TUNNELS	Figure 2



NOTE. 39'-6" LONG ROCK BOLT WAS COUPLED TO FACILITATE INSTALLATION (COUPLINGS NOT SHOWN).

NO SCALE

PRELIMINARY DRAFT

SCHEMATIC OF ROCK BOLT LOAD CELL INSTALLATIONS

Project No 87H249C	Date 01/31/90	Project SAN ANTONIO TUNNELS	Fig 3

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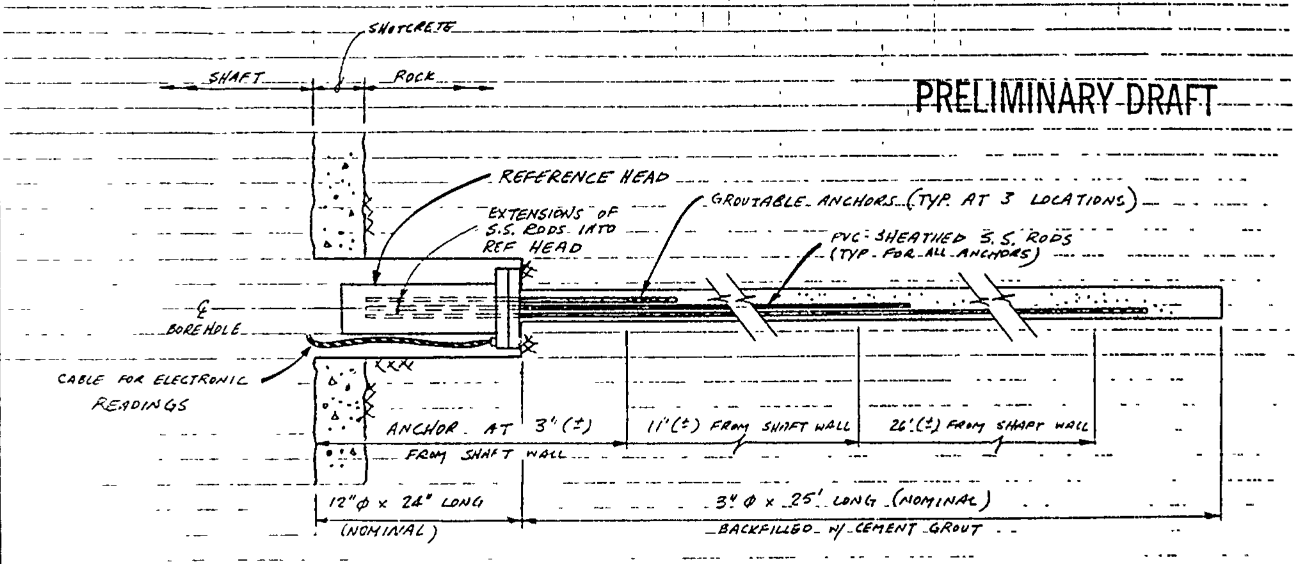
PRELIMINARY DRAFT



NOTE SIX-POSITION BOREHOLE EXTENSOMETER INSTALLATION IS SIMILAR, WITH FOLLOWING EXCEPTIONS:

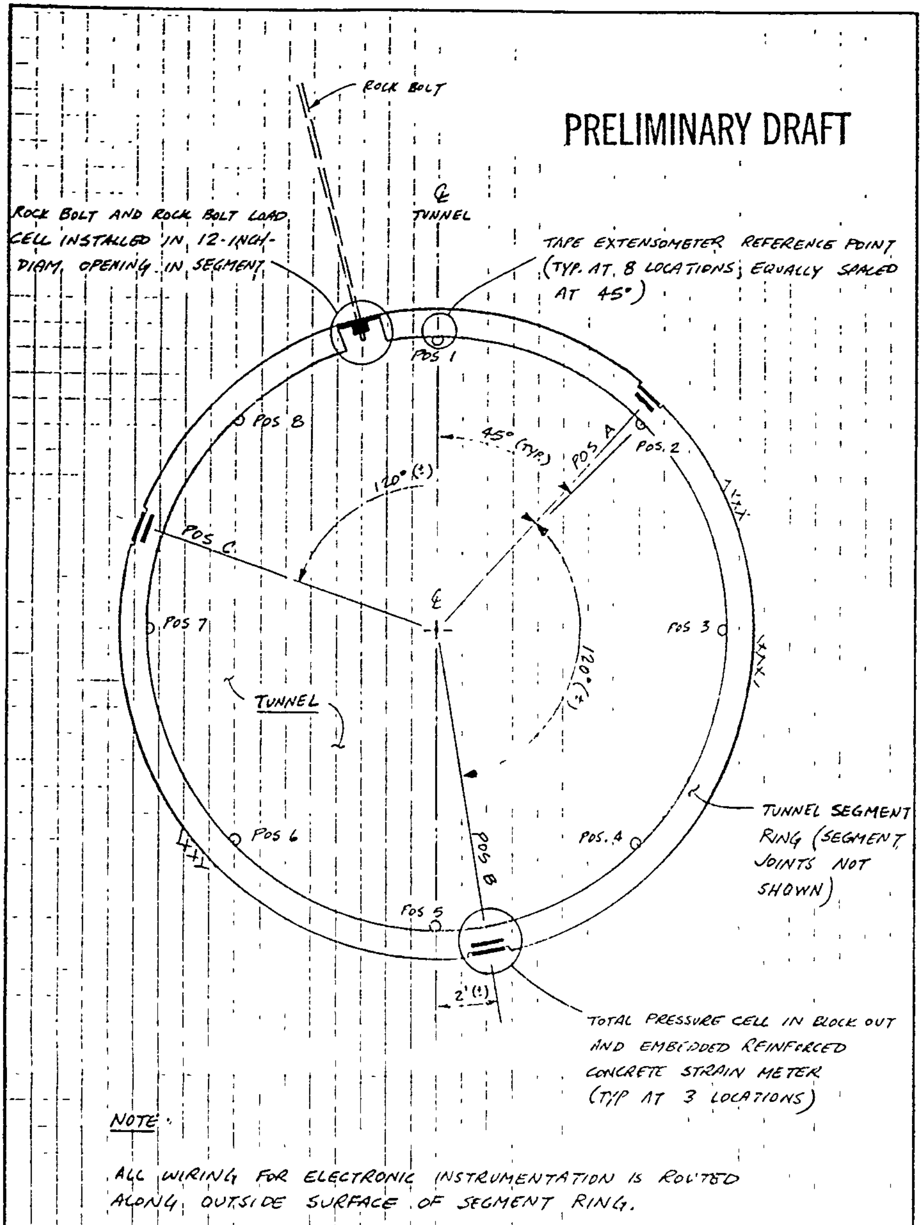
- INSTALLATION IS VERTICAL, WITH REF HEAD AT GROUND SURFACE.
- THERE ARE SIX ANCHORS PER EXTENSOMETER, INSTALLED AT DEPTHS INDICATED ON PROJECT PLANS.
- A PORTION OF THE BOREHOLE IS 6-IN. DIAM. AND CASED WITH STEEL.

NO SCALE

SCHEMATIC OF BOREHOLE EXTENSOMETER INSTALLATIONS

Project No 87H249C	Date 01/31/90	Project SAN ANTONIO TUNNELS	Fig. 4

Woodward-Clyde Consultants



SCHEMATIC OF TUNNEL INSTRUMENTATION INSTALLATIONS

Project No. 87H249C	Date 01/31/90	Project SAN ANTONIO TUNNELS	Fig 5

TABLE 1

San Antonio River and San Pedro Creek Tunnels Project

GEOTECHNICAL INSTRUMENTATION INSTALLED IN SAN PEDRO CREEK OUTLET SHA

INSTRUMENTATION ELEVATION (approx.)	INSTRUMENT QUANTITIES & TYPES	PRE-INSTALLATION SUBMITTAL(S)	INSTALLATION DATE	INSTALLATION REPORT(S)	RELEVANT DATA REPORTS	SEMI-FINAL READING (see note 1)	INSTRUMENT STATUS (see note 2)
Elev. 604	4 - 3 position borehole extensometers	22 Dec. '87 28 Jan. '88	3 Mar. '88	23 Mar. '88 24 Mar. '88 24 Mar. '88 28 Mar. '88	28 Mar. '88 26 May '88 27 June '88 16 Aug. '88 20 Sep. '88 28 Sep. '88 21 Oct. '88 7 Feb. '89 8 June '89 25 Aug. '89	21 and 30 Nov. '89	Pos. A must be read manually
Elev. 596	4 - rock bolt load cells	22 Dec. '87 28 Jan. '88 1 Feb. '88 19 Feb. '88 25 Feb. '88 29 Feb. '88	18-22 Mar. '88	23 Mar. '88 24 Mar. '88 24 Mar. '88 28 Mar. '88 8 June '88	28 Mar. '88 26 May '88 27 June '88 16 Aug. '88 20 Sep. '88 21 Oct. '88 7 Feb. '89 8 June '89 25 Aug. '89	21 Nov. '89	
Elev. 575	4 ea. - 3 pos. borehole extensometers, rock bolt load cells	22 Dec. '87 28 Jan. '88 1 Feb. '88 19 Feb. '88 25 Feb. '88 29 Feb. '88	8-11 Apr. '88	14 Apr. '88 20 Apr. '88 8 June '88	26 May '88 27 June '88 16 Aug. '88 20 Sep. '88 21 Oct. '88 7 Feb. '89 8 June '89 25 Aug. '89	21 and 30 Nov. '89	Pos. A extensometer must be read manually
Elev. 550	4 ea. - 3 pos. borehole extensometers, rock bolt load cells	22 Dec. '87 28 Jan. '88 1 Feb. '88 19 Feb. '88 25 Feb. '88 29 Feb. '88 20 Apr. '88	6 May '88	23 May '88 26 May '88 8 June '88	26 May '88 16 June '88 27 June '88 16 Aug. '88 20 Sep. '88 21 Oct. '88 7 Feb. '89 8 June '89 25 Aug. '89	24 Oct. '89 and 21 Nov. '89	Pos. A extensometer must be read manually

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TABLE 1

San Antonio River and San Pedro Creek Tunnels Project

OTECHNICAL INSTRUMENTATION INSTALLED IN SAN PEDRO CREEK OUTLET SHAFT

INSTALLATION DATE	INSTALLATION REPORT(S)	RELEVANT DATA REPORTS	SEMI-FINAL READING (see note 1)	INSTRUMENT STATUS (see note 2)
3 Mar. '88	23 Mar. '88 24 Mar. '88 24 Mar. '88 28 Mar. '88	28 Mar. '88 26 May '88 27 June '88 16 Aug. '88 20 Sep. '88 28 Sep. '88 21 Oct. '88 7 Feb. '89 8 June '89 25 Aug. '89	21 and 30 Nov. '89	Pos. A must be read manually
18-22 Mar. '88	23 Mar. '88 24 Mar. '88 24 Mar. '88 28 Mar. '88 8 June '88	28 Mar. '88 26 May '88 27 June '88 16 Aug. '88 20 Sep. '88 21 Oct. '88 7 Feb. '89 8 June '89 25 Aug. '89	21 Nov. '89	
8-11 Apr. '88	14 Apr. '88 20 Apr. '88 8 June '88	26 May '88 27 June '88 16 Aug. '88 20 Sep. '88 21 Oct. '88 7 Feb. '89 8 June '89 25 Aug. '89	21 and 30 Nov. '89	Pos. A extensometer must be read manually
6 May '88	23 May '88 26 May '88 8 June '88	26 May '88 16 June '88 27 June '88 16 Aug. '88 20 Sep. '88 21 Oct. '88 7 Feb. '89 8 June '89 25 Aug. '89	24 Oct. '89 and 21 Nov. '89	Pos. A extensometer must be read manually

NOTES:

1. "FINAL" READINGS WILL BE TAKEN PRIOR TO PREPARATION OF FINAL SAN PEDRO CREEK TUNNEL AND OUTLET SHAFT INSTRUMENTATION REPORT, PENDING AVAILABLE ACCESS.

2. "INSTRUMENT STATUS" IS APPLICABLE AS OF THE DATE OF THE SEMI-FINAL READINGS.

2

PRELIMINARY DRAFT

TABLE 2

San Antonio River and San Pedro Creek Tunnels Project

GEOTECHNICAL INSTRUMENTATION INSTALLED IN SAN PEDRO CREEK TUNNEL

INSTRUMENTATION STATION (approx.)	INSTRUMENT QUANTITIES & TYPES	PRE-INSTALLATION SUBMITTAL(S)	INSTALLATION DATE	INSTALLATION REPORT(S)	RELEVANT DATA REPORTS	SEMI-FINAL READING (see note 2)	INSTRUMENT STATUS (see note 3)
Sta. 143+75	* 1 - 6 pos. borehole extensometer	22 Dec. '87 5 Feb. '88 6 June '88 5 July '88	13 July '88	4 Aug. 88	21 Dec. '88 21 Feb. '89 8 June '89 25 Aug. '89	21 Nov. '89	
	* 18 displacement markers 1	19 May '88	9 Aug. '88(?)	11 Aug. '88	21 Dec. '88 21 Feb. '89 2 Aug. '89	10 Jan. '90	8 markers have been disturbed or destroyed
	* 1 - rock bolt load cell; 3 - total pressure cells; 3 - reinf. concrete strain meters; 8 convergence points	13 May '88 8 June '88 6 July '88 9 Aug. '88	30 Dec. '88	7 Feb. '89	21 Feb. '89 15 Mar. '89 12 Apr. '89 8 June '89 25 Aug. '89	21 Nov. '89 and 9 Jan. '90	Pos. B strain meter cannot be read
	* Borescope observations	2 Aug. '88 12 Oct. '88	Jan.-Feb. '89	9 Feb. '89 and 25 Mar. '89	Not applicable	Not applicable	Not applicable
Sta. 158+47	* 1 - 6 pos. borehole extensometer	5 Feb. '88 6 June '88 5 July '88	18 July '88	4 Aug. '88	26 Apr. '89 8 June '89 25 Aug. '89	21 Nov. '89	
	* 1 - rock bolt load cell; 3 - total pressure cells; 3 - reinf. concrete strain meters; 6 convergence points	13 May '88 2 June '88 8 June '88 6 July '88 12 July '88 9 Aug. '88	21-27 Mar. '89	14 Apr. '89	26 Apr. '89 8 June '89 25 Aug. '89	21 Nov. '89 and 9 Jan. '90	Pos. A press. cell cannot be read
	* Borescope observations	2 Aug. '88 12 Oct. '88	Mar. '89	14 Apr. '89	Not applicable	Not applicable	Not applicable

TABLE 2

San Antonio River and San Pedro Creek Tunnels Project

GEOTECHNICAL INSTRUMENTATION INSTALLED IN SAN PEDRO CREEK TUNNEL

TION S)	INSTALLATION DATE	INSTALLATION REPORT(S)	RELEVANT DATA REPORTS	SEMI-FINAL READING (see note 2)	INSTRUMENT STATUS (see note 3)
87 8 8 8	13 July '88	4 Aug. 88	21 Dec. '88 21 Feb. '89 8 June '89 25 Aug. '89	21 Nov. '89	
8	9 Aug. '88(?)	11 Aug. '88	21 Dec. '88 21 Feb. '89 2 Aug. '89	10 Jan. '90	8 markers have been disturbed or destroyed
8 8 8 8	30 Dec. '88	7 Feb. '89	21 Feb. '89 15 Mar. '89 12 Apr. '89 8 June '89 25 Aug. '89	21 Nov. '89 and 9 Jan. '90	Pos. B strain meter cannot be read
8 88	Jan.-Feb. '89	9 Feb. '89 and 23 Mar. '89	Not applicable	Not applicable	Not applicable
8 8 8	18 July '88	4 Aug. '88	26 Apr. '89 8 June '89 25 Aug. '89	21 Nov. '89	
8 8 8 8 58 8	21-27 Mar. '89	14 Apr. '89	26 Apr. '89 8 June '89 25 Aug. '89	21 Nov. '89 and 9 Jan. '90	Pos. A press. cell cannot be read
8 88	Mar. '89	14 Apr. '89	Not applicable	Not applicable	Not applicable

2

NOTES:

1. "FINAL" READINGS WILL BE TAKEN PRIOR TO PREPARATION OF FINAL SAN PEDRO CREEK TUNNEL AND OUTLET SHAFT INSTRUMENTATION REPORT, PENDING AVAILABLE ACCESS.

2. "INSTRUMENT STATUS" IS APPLICABLE AS OF THE DATE OF THE SEMI-FINAL READINGS.

PRELIMINARY DRAFT

TABLE 3

San Antonio River and San Pedro Creek Tunnels Project

GEOTECHNICAL INSTRUMENTATION INSTALLED IN SAN PEDRO CREEK TUNNEL AND OUTLET SHAFT

INSTRUMENTATION TYPE	INSTRUMENT MODEL (see note 1)	INSTRUMENT QUANTS. & LOCATIONS (see note 2)	NOTES
Three-position Borehole Extensometer	A-3-1500	Outlet Shaft: # 4 at Elev. 604 # 4 at Elev. 575 # 4 at Elev. 550	May be read electronically or manually
Rock Bolt Load Cell	4900-50-1.0	Outlet Shaft: # 4 at Elev. 596 # 4 at Elev. 575 # 4 at Elev. 550 Tunnel: # 1 at Sta. 143+75 # 1 at Sta. 158+47	Load cell has 50-ton capacity
Six-Position Borehole Extensometer	A-3-1500	Tunnel: # 1 at Sta. 143+75 # 1 at Sta. 158+47	May be read electronically or manually
Total Pressure Cell	4800E	Tunnel: # 3 at Sta. 143+75 # 3 at Sta. 158+47	Pos. A cell cannot be read
Reinforced Concrete Strain Meter	4911 Sister Bar	Tunnel: # 3 at Sta. 143+75 # 3 at Sta. 158+47	Pos. B meter cannot be read
Convergence Reference Points	Points: N/A Tape Extensometer: 1600-1	Tunnel: # 8 at Sta. 143+75 # 6 at Sta. 158+47	Invert point has been destroyed Crown and invert points were not installed
Displacement Markers	N/A	18 between Tunnel Stations 143+00 and 145+00	8 markers have been disturbed or destroyed
Borescope	Instrument Technology, Inc. model 122500 (extendable)	7 boreholes x 8 ft. long at Tunnel Stations 143+63, 143+71, 143+79, 143+87, 143+95, 158+39, 158+47, and 158+55	

PRELIMINARY DRAFT

NOTES:

1. ALL INSTRUMENTS WERE MANUFACTURED BY, AND PURCHASED FROM, GEOKON, INC., EXCEPT THE BORESCOPE.
2. LISTED ELEVATIONS AND STATIONS ARE APPROXIMATE.

Woodward-Clyde Consultants

APPENDIX A

REPORTS OF RAW AND REDUCED INSTRUMENTATION DATA

(NOT INCLUDED)

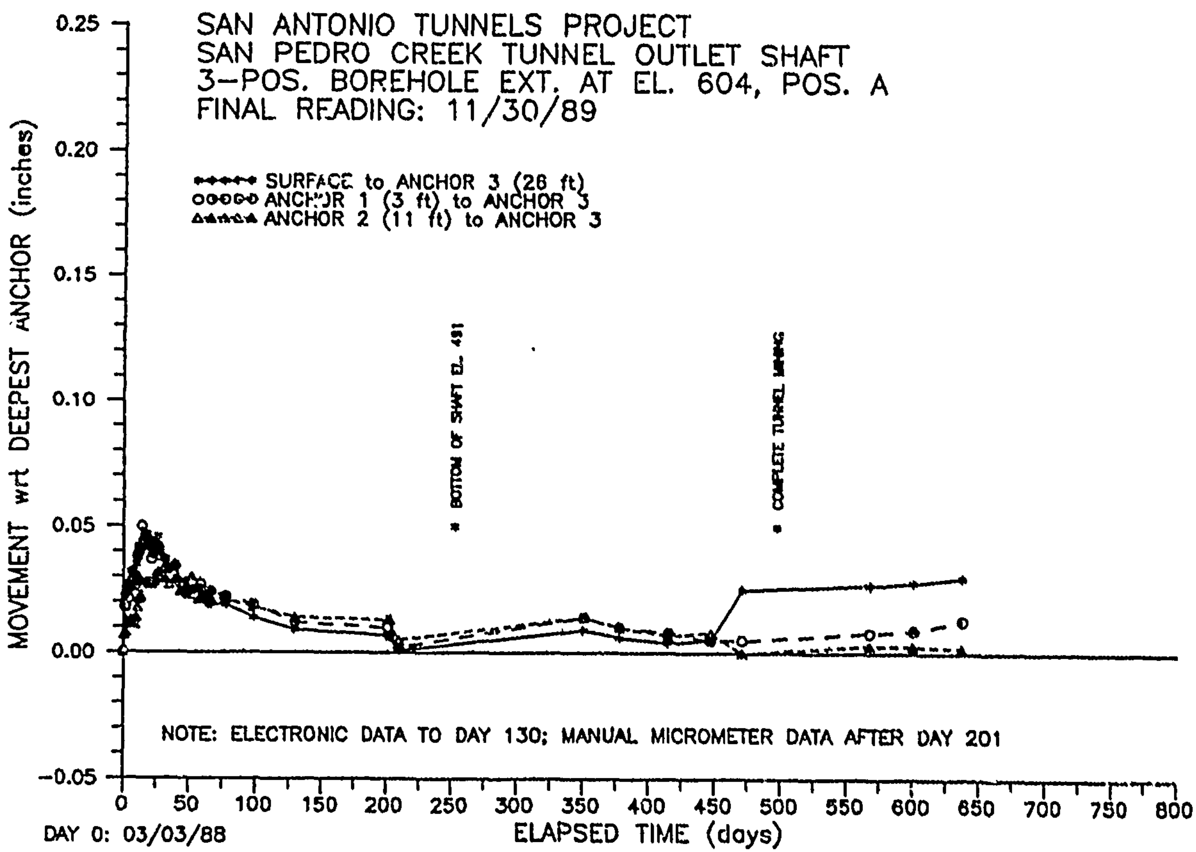
APPENDIX B

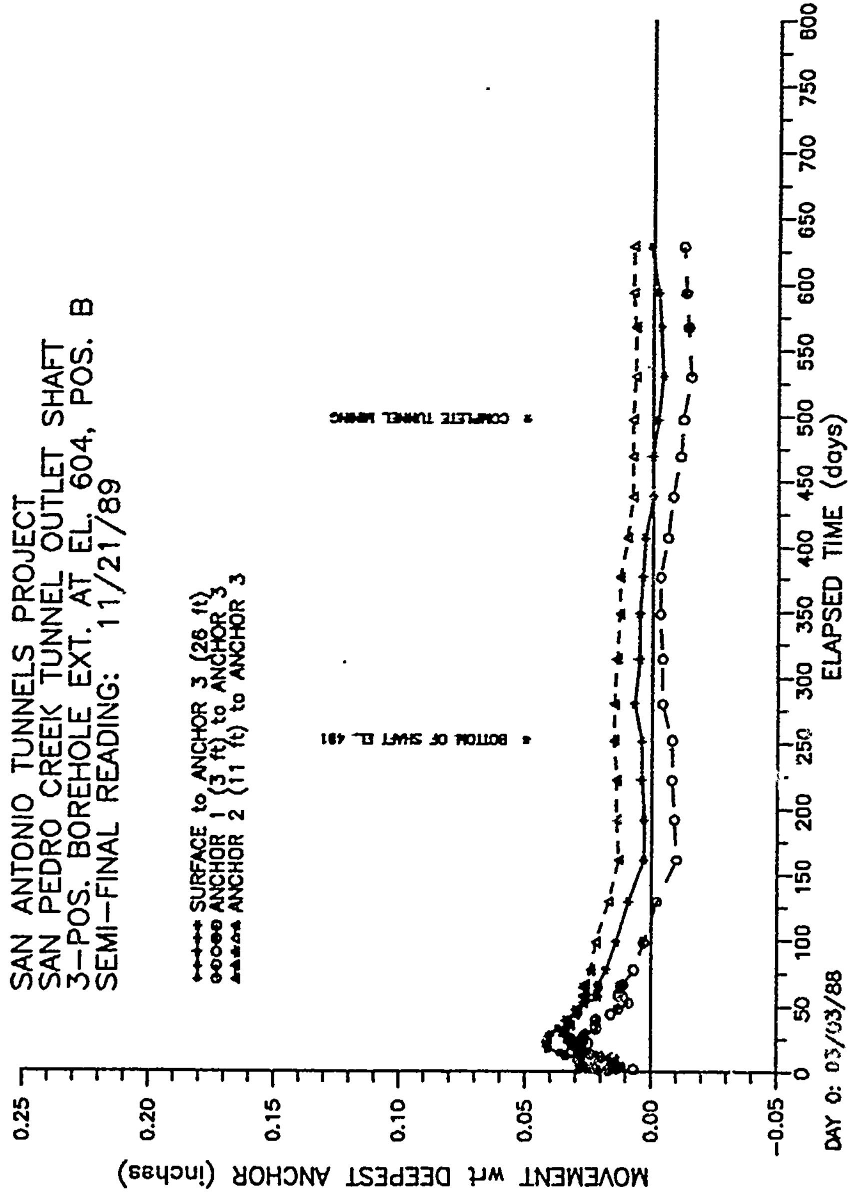
PLOTS OF REDUCED INSTRUMENTATION DATA

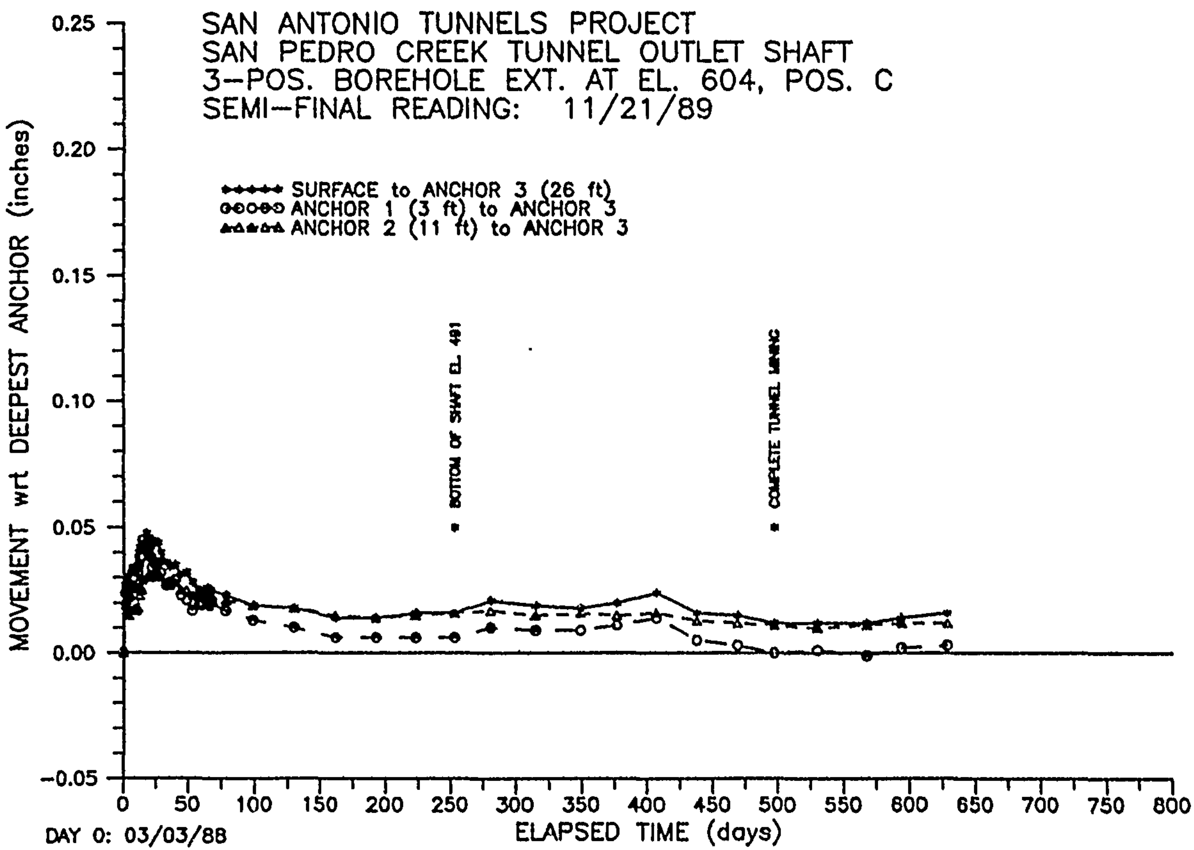
DRAFT FINAL INSTRUMENTATION REPORT FOR THE
SAN PEDRO CREEK TUNNEL AND OUTLET SHAFT

SAN ANTONIO RIVER AND SAN PEDRO CREEK TUNNELS PROJECT
WCC PROJECT NO. 87H249C

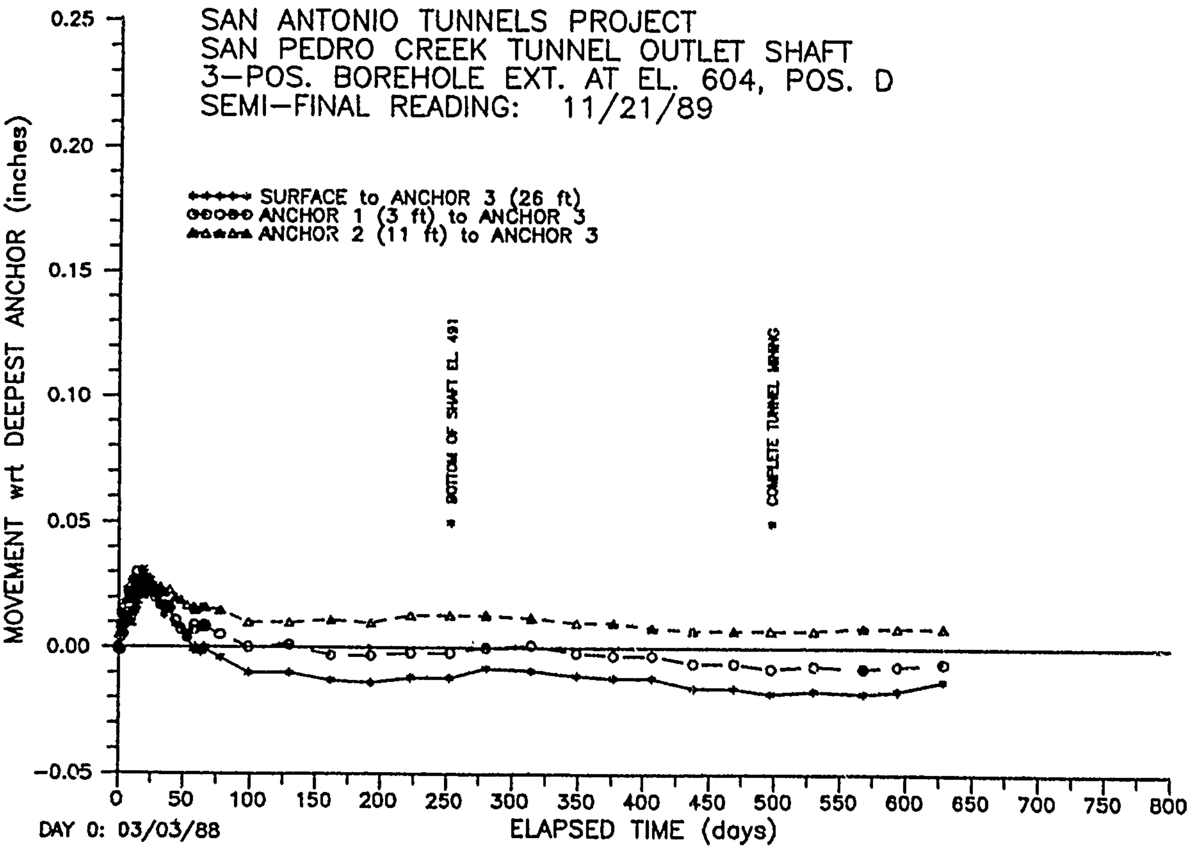
OUTLET SHAFT


SAN ANTONIO TUNNELS PROJECT
SAN PEDRO CREEK TUNNEL OUTLET SHAFT
3–POS. BOREHOLE EXT. AT EL. 604, POS. A
FINAL READING: 11/30/89
SURFACE to ANCHOR 3 (26 ft)
ANCHOR 1 (3 ft) to ANCHOR 3
ANCHOR 2 (11 ft) to ANCHOR 3
BOTTOM OF SHAFT EL. 481
COMPLETE TUNNEL MINING
NOTE: ELECTRONIC DATA TO DAY 130; MANUAL MICROMETER DATA AFTER DAY 201
MOVEMENT wrt DEEPEST ANCHOR (inches)
0.25
0.20
0.15
0.10
0.05
0.00
−0.05
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800
DAY 0: 03/03/88
ELAPSED TIME (days)

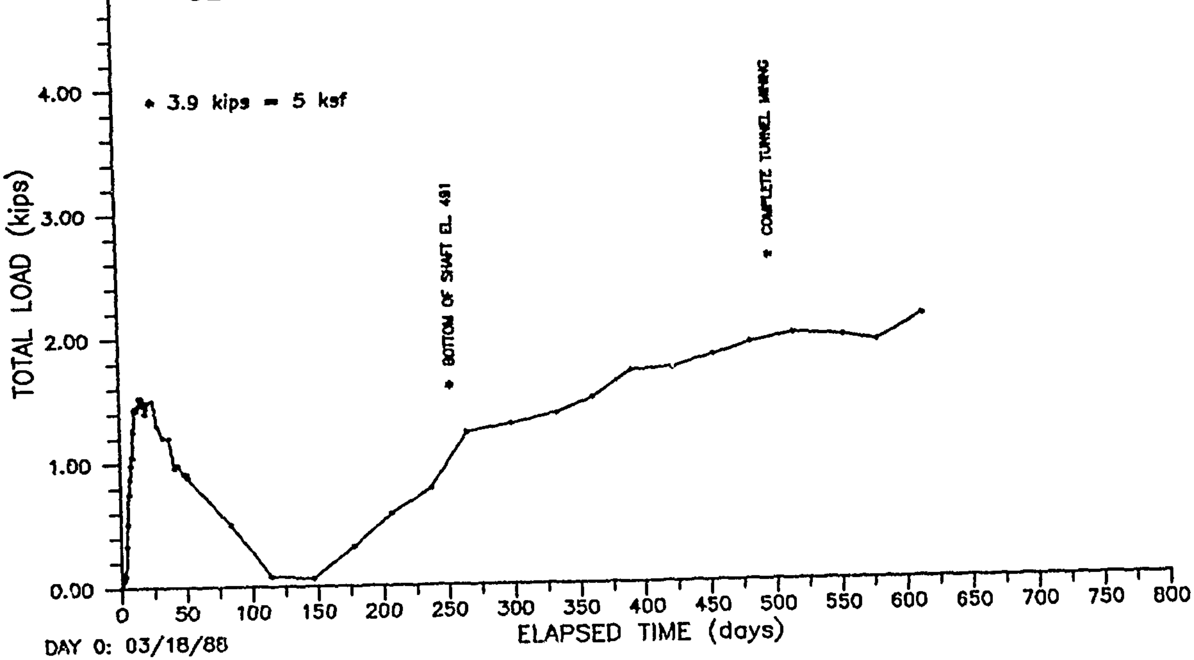

SAN ANTONIO TUNNELS PROJECT
SAN PEDRO CREEK TUNNEL OUTLET SHAFT
3–POS. BOREHOLE EXT. AT EL. 604, POS. B
SEMI–FINAL READING: 11/21/89
SURFACE to ANCHOR 3 (26 ft)
ANCHOR 1 (3 ft) to ANCHOR 3
ANCHOR 2 (11 ft) to ANCHOR 3
BOTTOM OF SHAFT EL. 481
COMPLETE TUNNEL MINING
MOVEMENT wrt DEEPEST ANCHOR (inches)
0.25
0.20
0.15
0.10
0.05
0.00
–0.05
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800
ELAPSED TIME (days)
DAY 0: 03/03/88



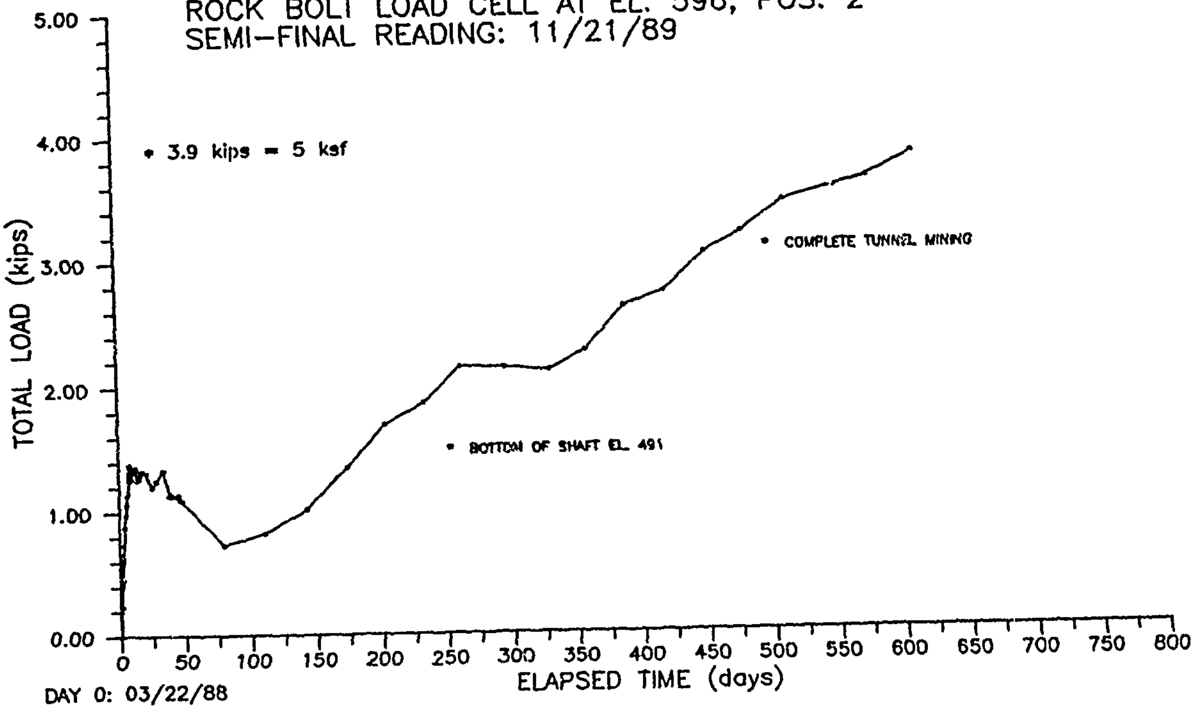
SAN ANTONIO TUNNELS PROJECT
SAN PEDRO CREEK TUNNEL OUTLET SHAFT
3-POS. BOREHOLE EXT. AT EL. 604, POS. C
SEMI-FINAL READING: 11/21/89
SURFACE to ANCHOR 3 (26 ft)
ANCHOR 1 (3 ft) to ANCHOR 3
ANCHOR 2 (11 ft) to ANCHOR 3
BOTTOM OF SHAFT EL. 491
COMPLETE TUNNEL MINING
MOVEMENT wrt DEEPEST ANCHOR (inches)
0.25
0.20
0.15
0.10
0.05
0.00
-0.05
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800
ELAPSED TIME (days)
DAY 0: 03/03/88

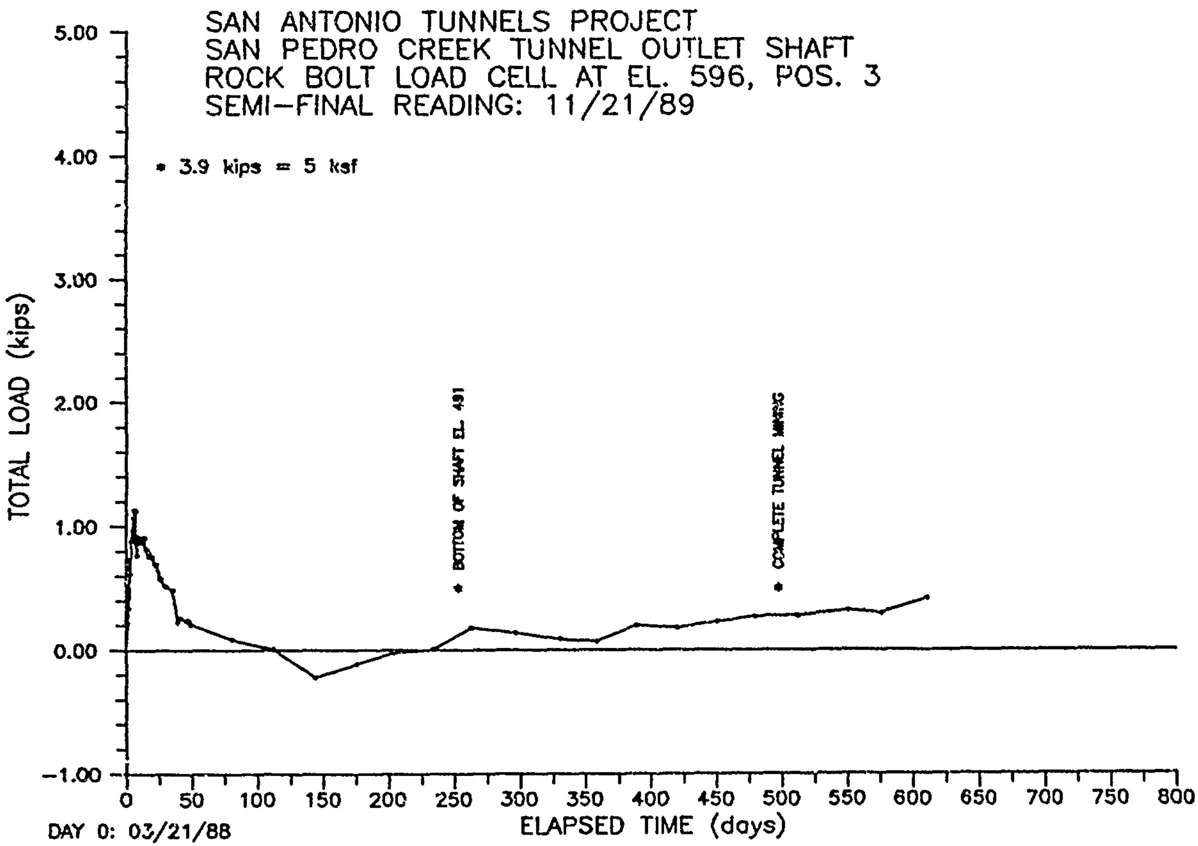

SAN ANTONIO TUNNELS PROJECT
SAN PEDRO CREEK TUNNEL OUTLET SHAFT
3-POS. BOREHOLE EXT. AT EL. 604, POS. D
SEMI-FINAL READING: 11/21/89
SURFACE to ANCHOR 3 (26 ft)
ANCHOR 1 (3 ft) to ANCHOR 3
ANCHOR 2 (11 ft) to ANCHOR 3
BOTTOM OF SHAFT EL. 491
COMPLETE TUNNEL MINING
MOVEMENT wrt DEEPEST ANCHOR (inches)
0.25
0.20
0.15
0.10
0.05
0.00
-0.05
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800
DAY 0: 03/03/88
ELAPSED TIME (days)

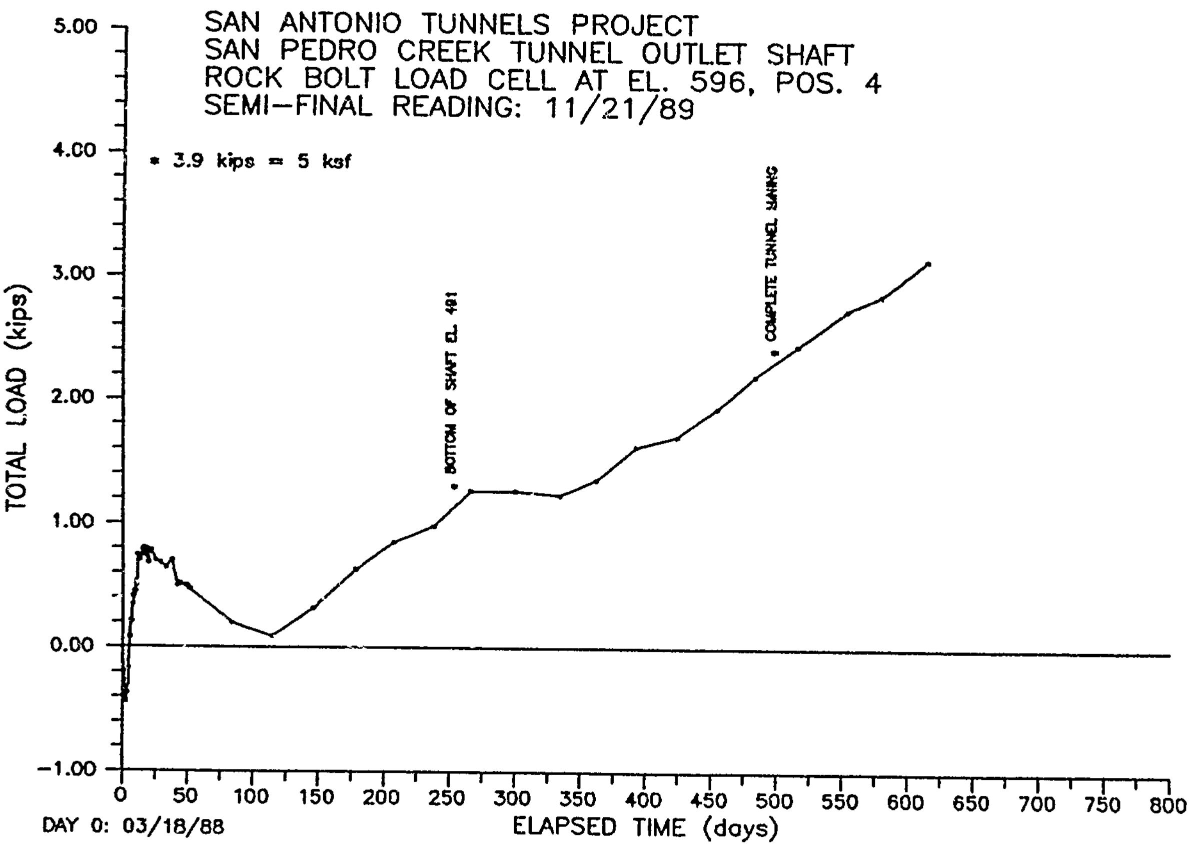
SAN ANTONIO TUNNELS PROJECT
SAN PEDRO CREEK TUNNEL OUTLET SHAFT
ROCK BOLT LOAD CELL AT EL. 596, POS. 1
SEMI-FINAL READING: 11/21/89



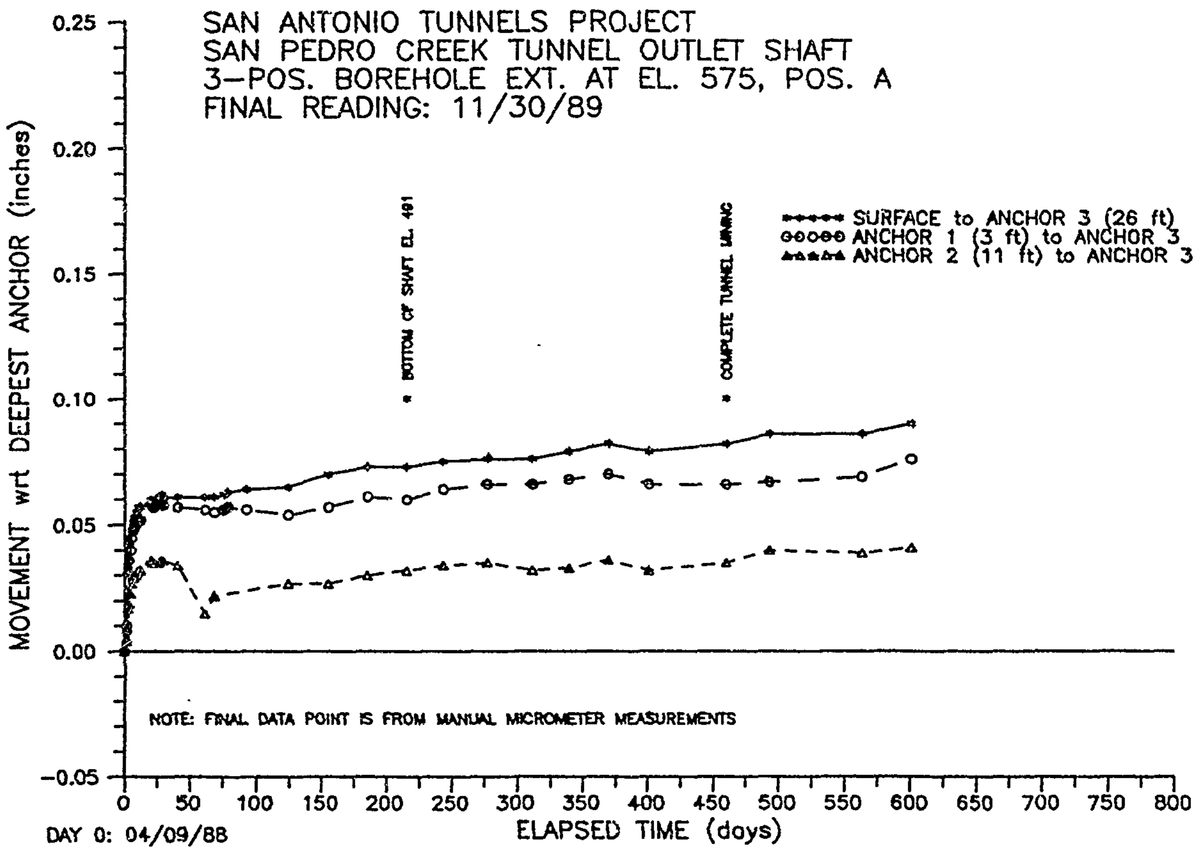
SAN ANTONIO TUNNELS PROJECT
SAN PEDRO CREEK TUNNEL OUTLET SHAFT
ROCK BOLT LOAD CELL AT EL. 596, POS. 2
SEMI-FINAL READING: 11/21/89

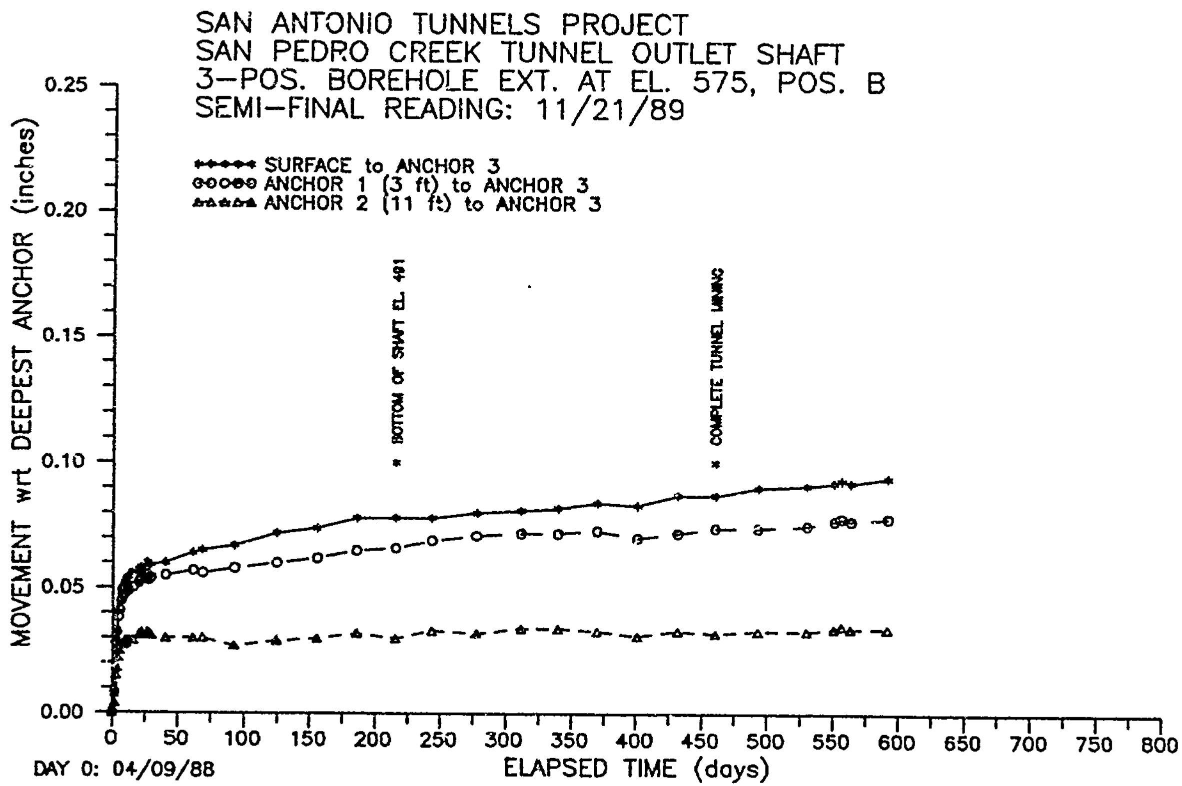



SAN ANTONIO TUNNELS PROJECT
SAN PEDRO CREEK TUNNEL OUTLET SHAFT
ROCK BOLT LOAD CELL AT EL. 596, POS. 3
SEMI-FINAL READING: 11/21/89
* 3.9 kips = 5 ksf
* BOTTOM OF SHAFT EL. 491
* COMPLETE TUNNEL MINING
TOTAL LOAD (kips)
5.00
4.00
3.00
2.00
1.00
0.00
-1.00
DAY 0: 03/21/88
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800
ELAPSED TIME (days)

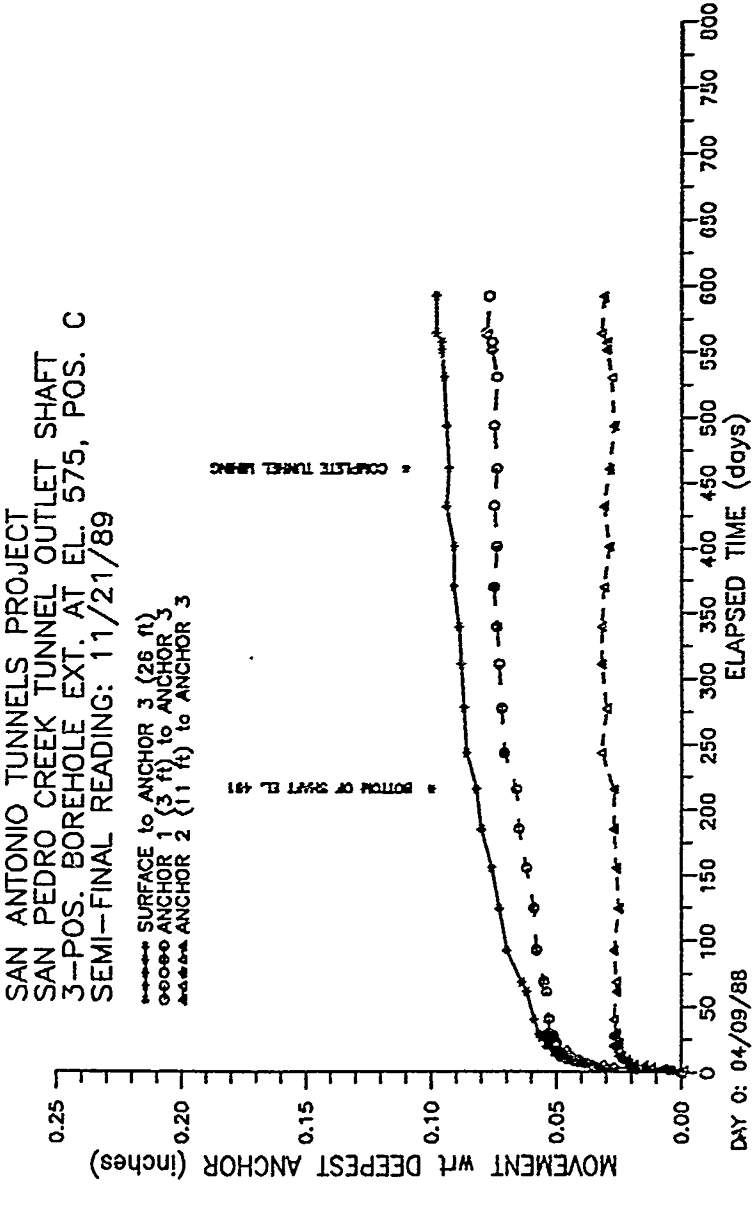


SAN ANTONIO TUNNELS PROJECT
SAN PEDRO CREEK TUNNEL OUTLET SHAFT
ROCK BOLT LOAD CELL AT EL. 596, POS. 4
SEMI-FINAL READING: 11/21/89
* 3.9 kips = 5 ksf
BOTTOM OF SHAFT EL. 481
COMPLETE TUNNEL MINING
TOTAL LOAD (kips)
5.00
4.00
3.00
2.00
1.00
0.00
-1.00
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800
DAY 0: 03/18/88
ELAPSED TIME (days)

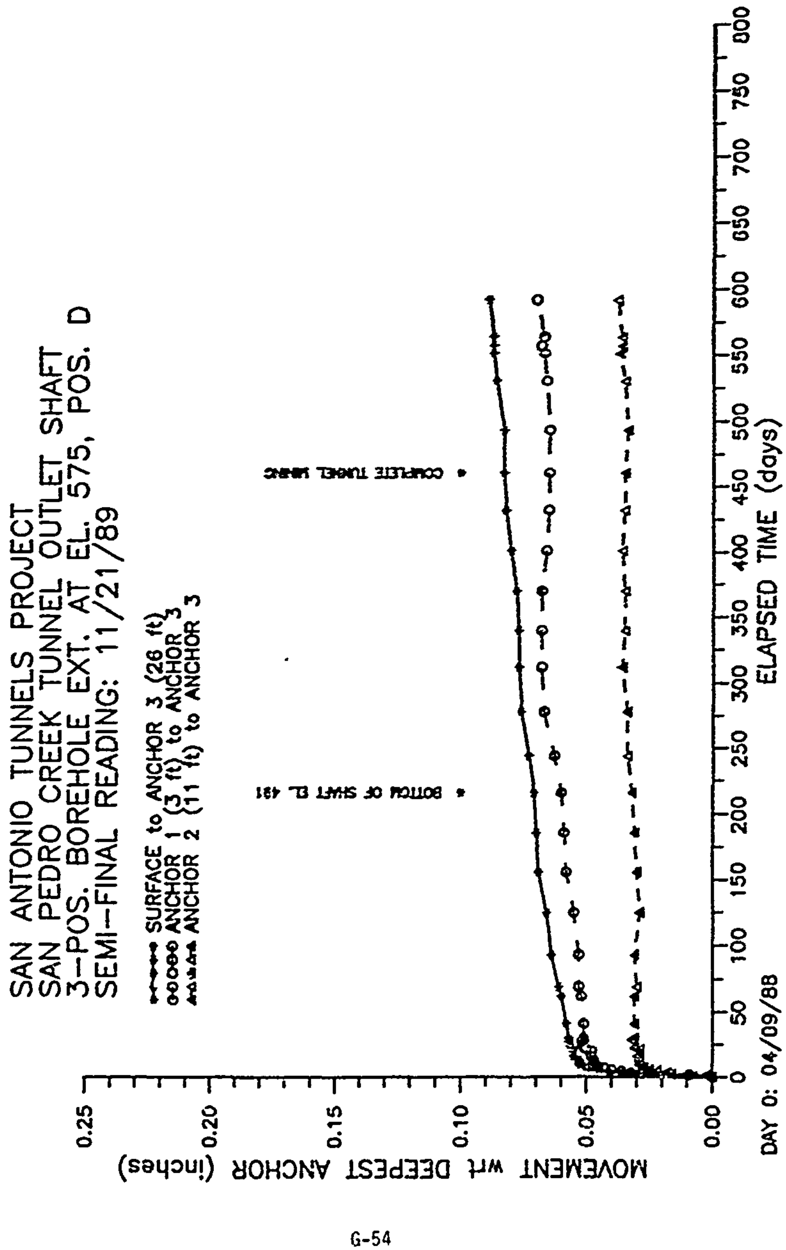

SAN ANTONIO TUNNELS PROJECT
SAN PEDRO CREEK TUNNEL OUTLET SHAFT
3–POS. BOREHOLE EXT. AT EL. 575, POS. A
FINAL READING: 11/30/89
MOVEMENT wrt DEEPEST ANCHOR (inches)
0.25
0.20
0.15
0.10
0.05
0.00
−0.05
* BOTTOM OF SHAFT EL. 491
* COMPLETE TUNNEL LINING
SURFACE to ANCHOR 3 (26 ft)
ANCHOR 1 (3 ft) to ANCHOR 3
ANCHOR 2 (11 ft) to ANCHOR 3
NOTE: FINAL DATA POINT IS FROM MANUAL MICROMETER MEASUREMENTS
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800
DAY 0: 04/09/88
ELAPSED TIME (days)



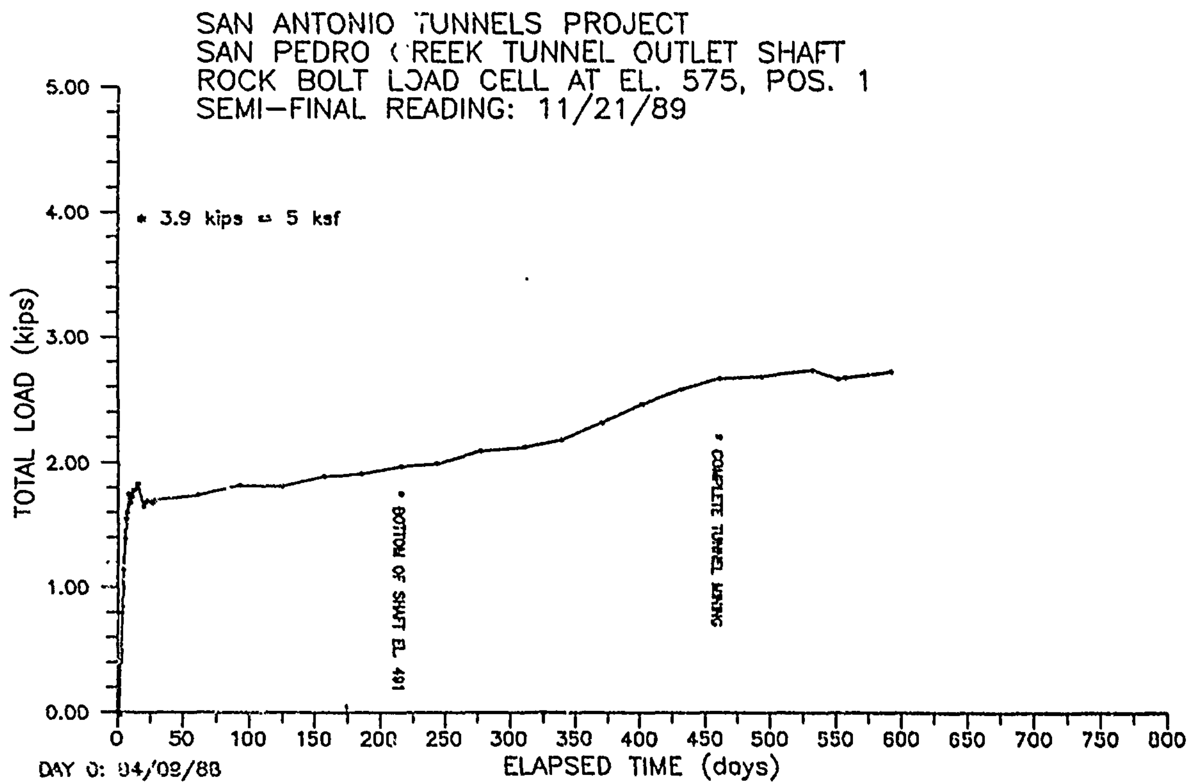
SAN ANTONIO TUNNELS PROJECT
SAN PEDRO CREEK TUNNEL OUTLET SHAFT
3-POS. BOREHOLE EXT. AT EL. 575, POS. B
SEMI-FINAL READING: 11/21/89
SURFACE to ANCHOR 3
ANCHOR 1 (3 ft) to ANCHOR 3
ANCHOR 2 (11 ft) to ANCHOR 3
* BOTTOM OF SHAFT EL. 491
* COMPLETE TUNNEL MINING
MOVEMENT wrt DEEPEST ANCHOR (inches)
0.00
0.05
0.10
0.15
0.20
0.25
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800
ELAPSED TIME (days)
DAY 0: 04/09/88

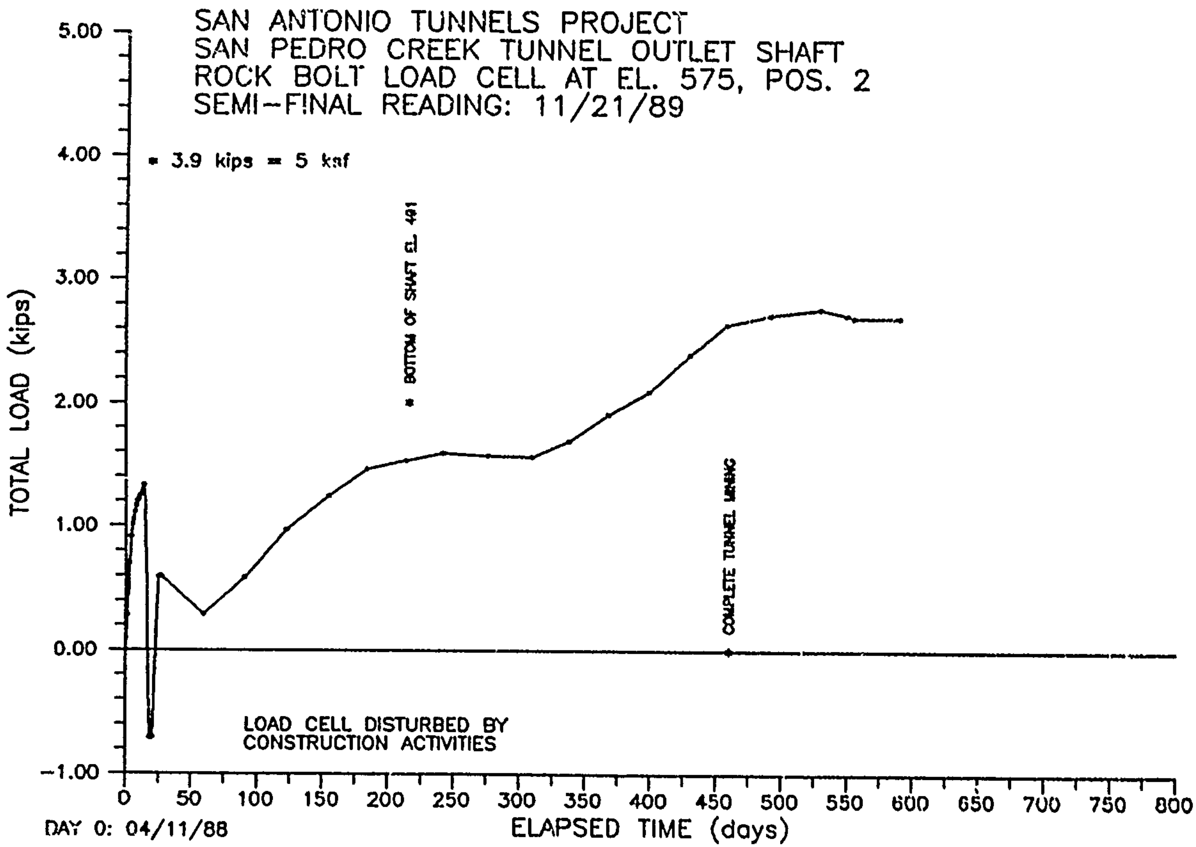


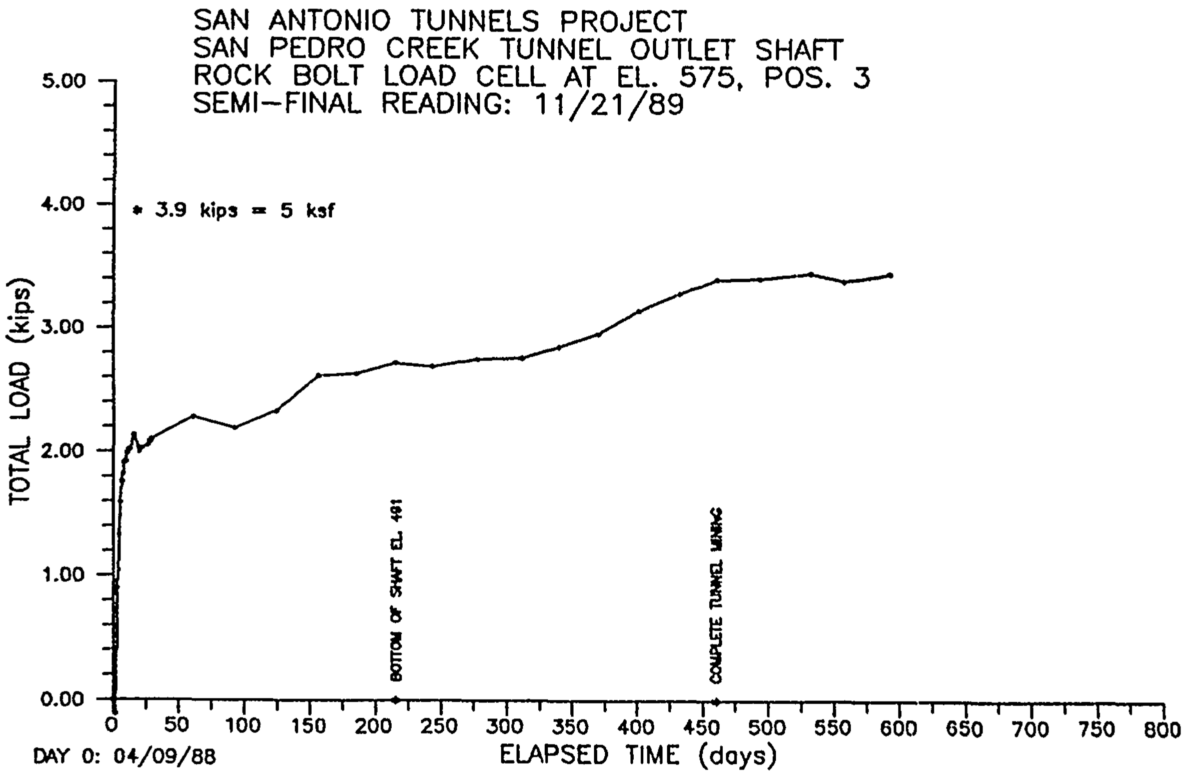
SAN ANTONIO TUNNELS PROJECT
SAN PEDRO CREEK TUNNEL OUTLET SHAFT
3-POS. BOREHOLE EXT. AT EL. 575, POS. C
SEMI-FINAL READING: 11/21/89
SURFACE to ANCHOR 3 (26 ft)
ANCHOR 1 (3 ft) to ANCHOR 3
ANCHOR 2 (11 ft) to ANCHOR 3
BOTTOM OF SHAFT EL 481
COMPLETE TUNNEL MINING
MOVEMENT wrt DEEPEST ANCHOR (inches)
0.25
0.20
0.15
0.10
0.05
0.00
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800
ELAPSED TIME (days)
DAY 0: 04/09/88

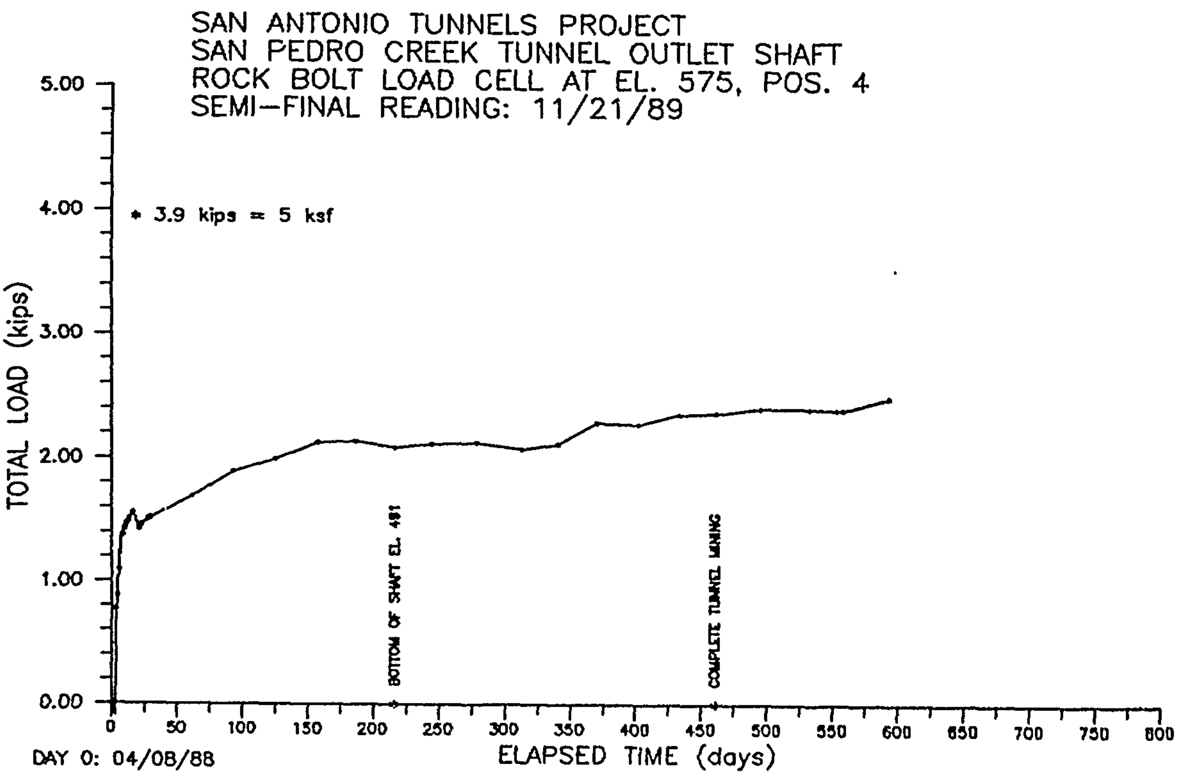


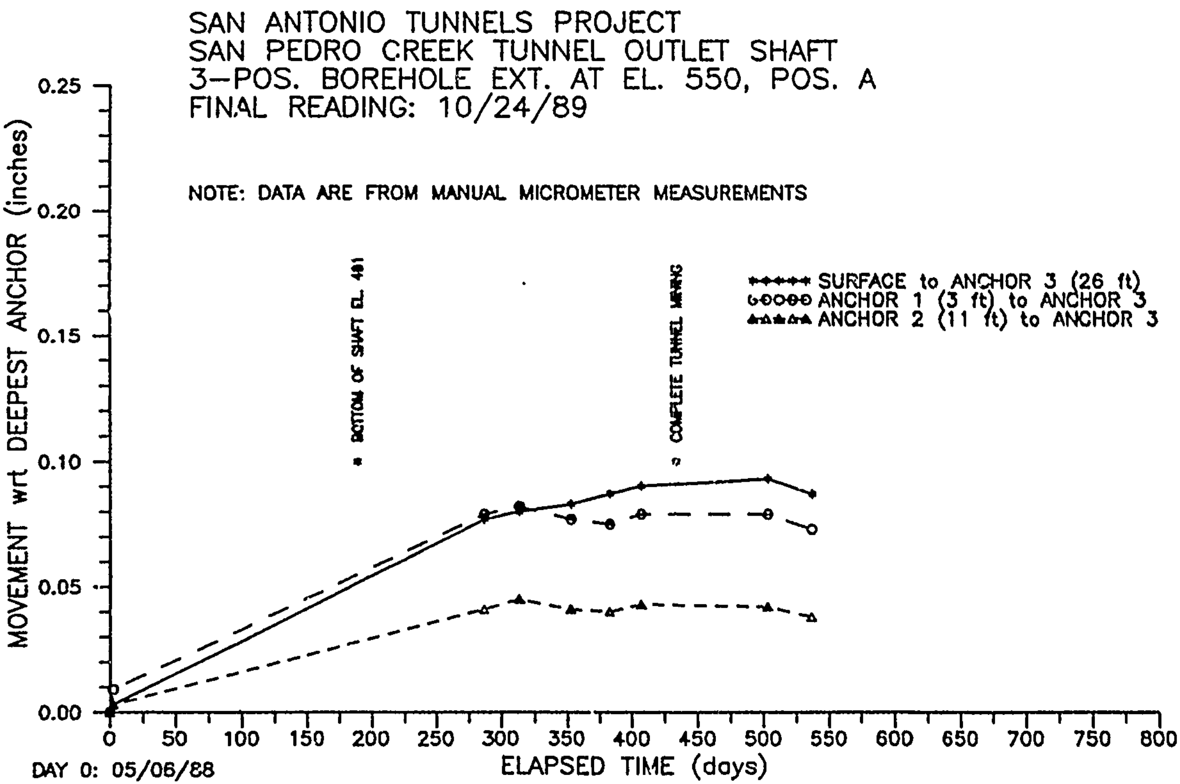
SAN ANTONIO TUNNELS PROJECT
SAN PEDRO CREEK TUNNEL OUTLET SHAFT
3–POS. BOREHOLE EXT. AT EL. 575, POS. D
SEMI–FINAL READING: 11/21/89
SURFACE to ANCHOR 3 (26 ft)
ANCHOR 1 (3 ft) to ANCHOR 3
ANCHOR 2 (11 ft) to ANCHOR 3
BOTTOM OF SHAFT EL. 491
COMPLETE TUNNEL MINING
MOVEMENT wrt DEEPEST ANCHOR (inches)
0.25
0.20
0.15
0.10
0.05
0.00
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800
ELAPSED TIME (days)
DAY 0: 04/09/88

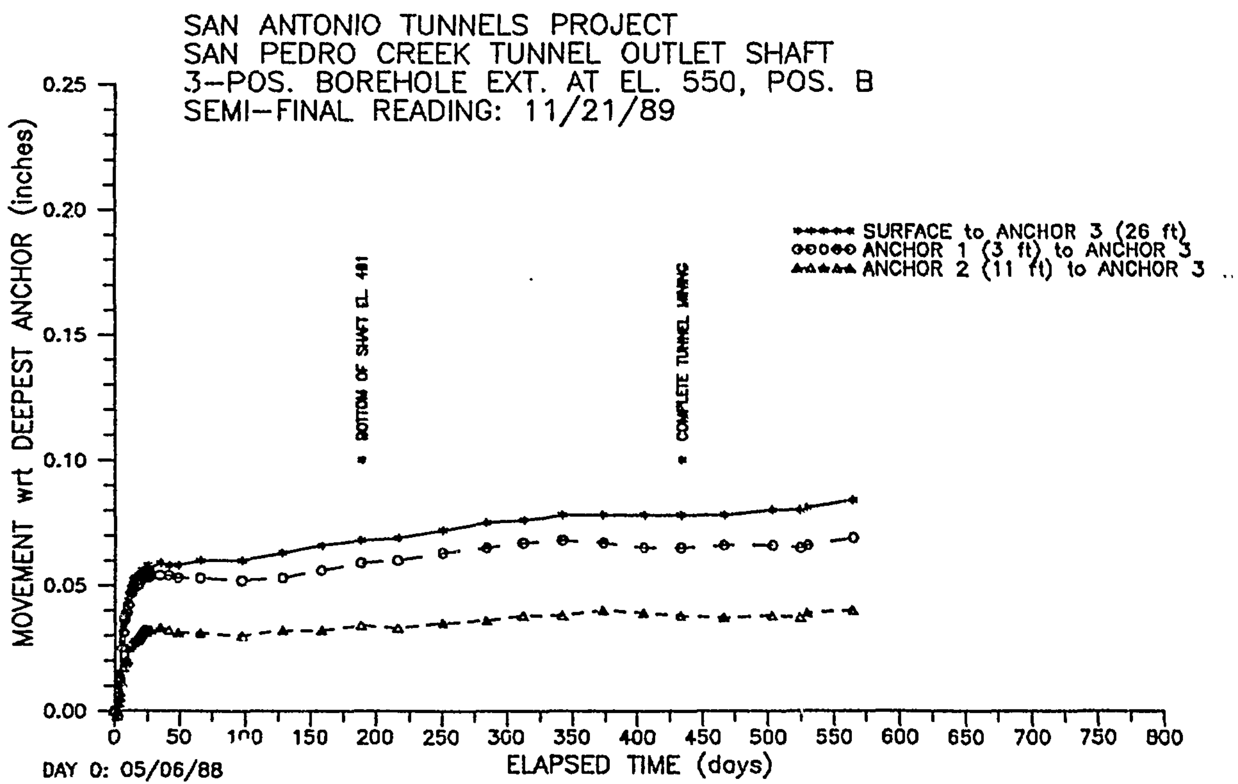

SAN ANTONIO TUNNELS PROJECT
SAN PEDRO CREEK TUNNEL OUTLET SHAFT
ROCK BOLT LOAD CELL AT EL. 575, POS. 1
SEMI-FINAL READING: 11/21/89
* 3.9 kips = 5 ksf
* BOTTOM OF SHAFT EL. 491
* COMPLETE TUNNEL MINING
TOTAL LOAD (kips)
0.00
1.00
2.00
3.00
4.00
5.00
ELAPSED TIME (days)
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800
DAY 0: 04/09/88

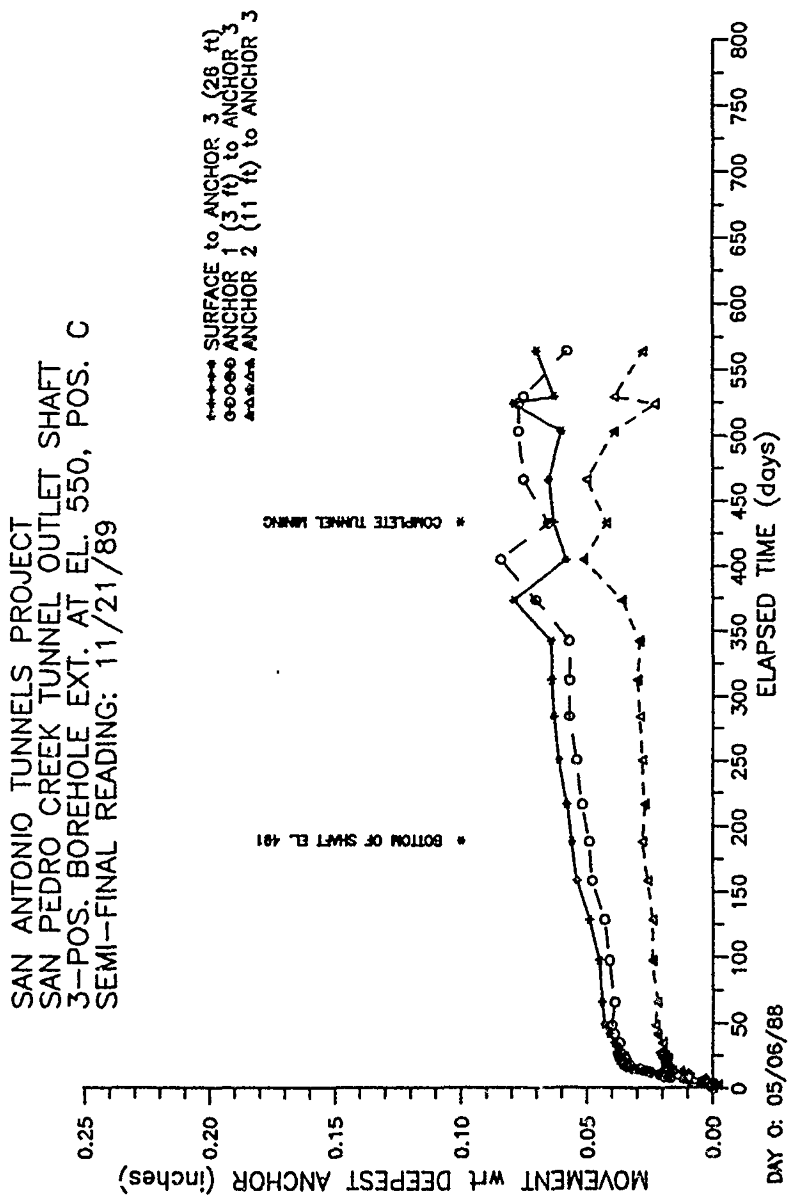

SAN ANTONIO TUNNELS PROJECT
SAN PEDRO CREEK TUNNEL OUTLET SHAFT
ROCK BOLT LOAD CELL AT EL. 575, POS. 2
SEMI-FINAL READING: 11/21/89
* 3.9 kips = 5 ksf
BOTTOM OF SHAFT EL. 491
COMPLETE TUNNEL MINING
LOAD CELL DISTURBED BY
CONSTRUCTION ACTIVITIES
TOTAL LOAD (kips)
5.00
4.00
3.00
2.00
1.00
0.00
-1.00
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800
DAY 0: 04/11/88
ELAPSED TIME (days)


SAN ANTONIO TUNNELS PROJECT
SAN PEDRO CREEK TUNNEL OUTLET SHAFT
ROCK BOLT LOAD CELL AT EL. 575, POS. 3
SEMI-FINAL READING: 11/21/89
* 3.9 kips = 5 ksf
TOTAL LOAD (kips)
5.00
4.00
3.00
2.00
1.00
0.00
BOTTOM OF SHAFT EL. 491
COMPLETE TUNNEL MINING
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800
DAY 0: 04/09/88
ELAPSED TIME (days)

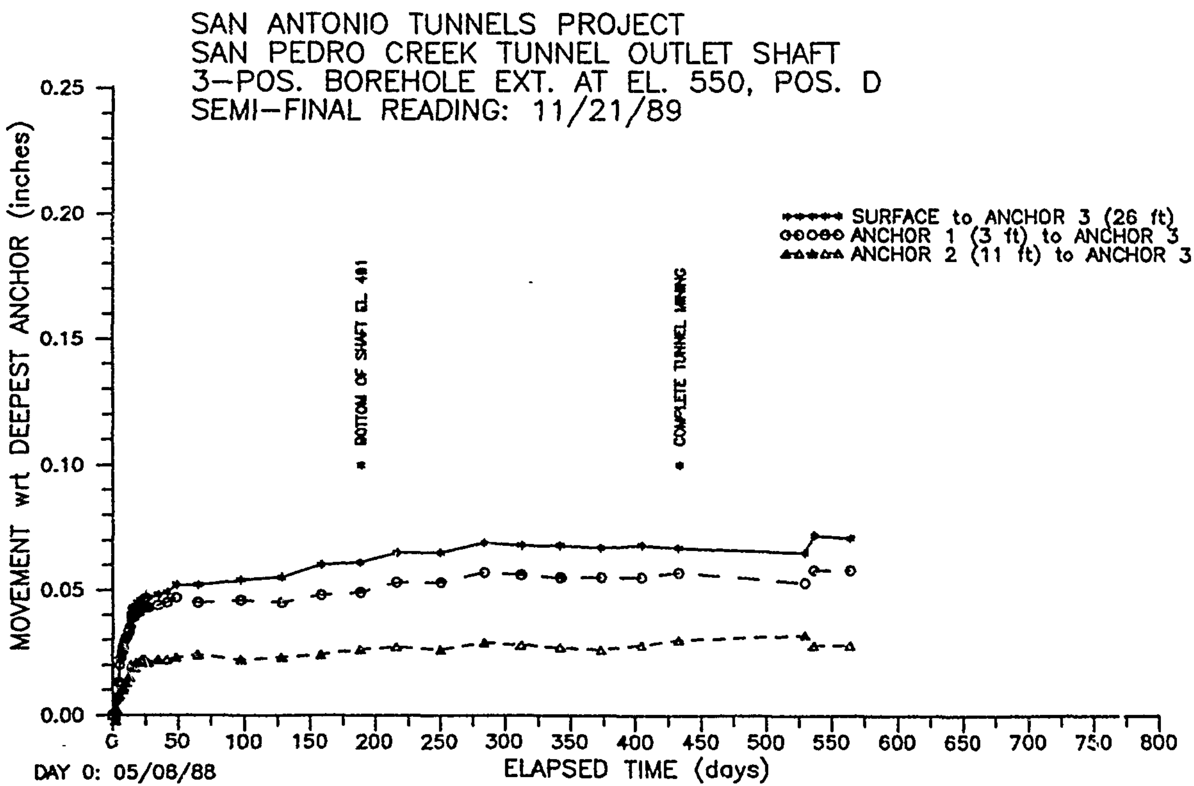

SAN ANTONIO TUNNELS PROJECT
SAN PEDRO CREEK TUNNEL OUTLET SHAFT
ROCK BOLT LOAD CELL AT EL. 575, POS. 4
SEMI-FINAL READING: 11/21/89
* 3.9 kips = 5 ksf
TOTAL LOAD (kips)
5.00
4.00
3.00
2.00
1.00
0.00
BOTTOM OF SHAFT EL. 481
COMPLETE TUNNEL MINING
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800
DAY 0: 04/08/88
ELAPSED TIME (days)

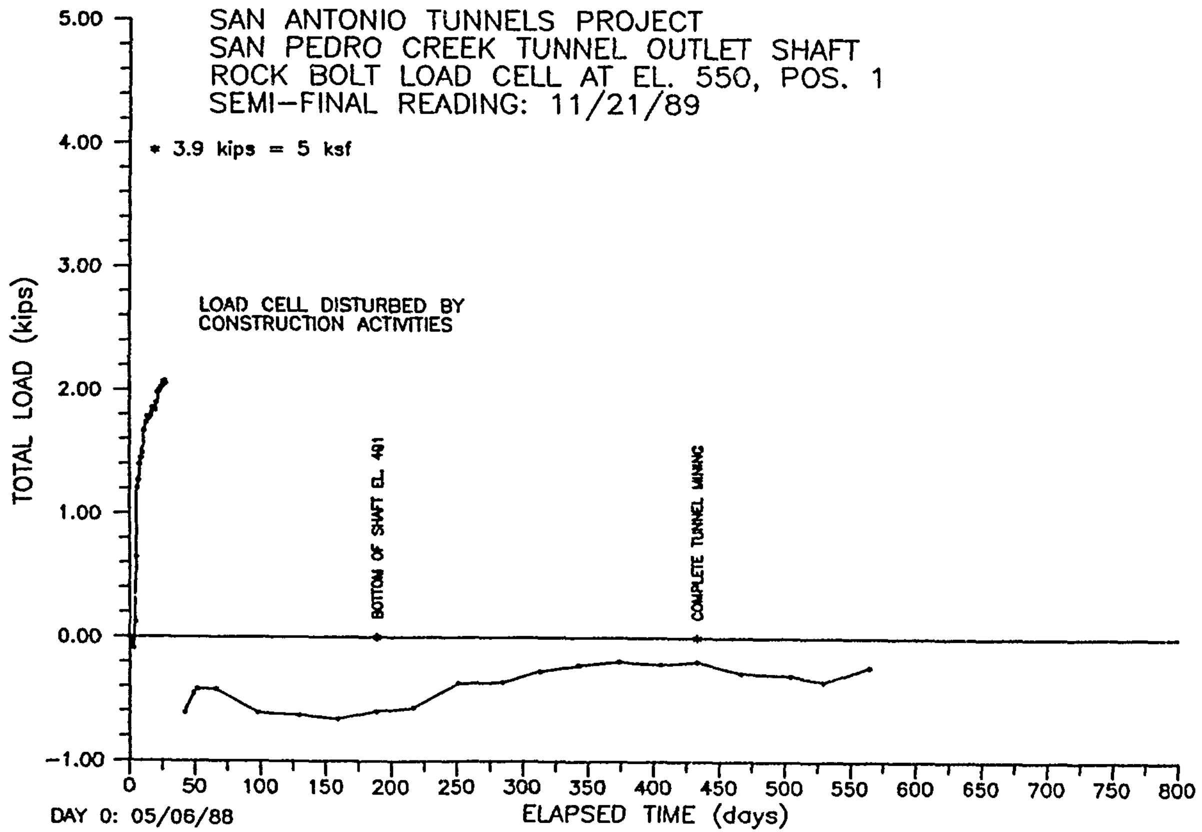

SAN ANTONIO TUNNELS PROJECT
SAN PEDRO CREEK TUNNEL OUTLET SHAFT
3-POS. BOREHOLE EXT. AT EL. 550, POS. A
FINAL READING: 10/24/89
NOTE: DATA ARE FROM MANUAL MICROMETER MEASUREMENTS
BOTTOM OF SHAFT EL. 481
COMPLETE TUNNEL MINING
SURFACE to ANCHOR 3 (26 ft)
ANCHOR 1 (3 ft) to ANCHOR 3
ANCHOR 2 (11 ft) to ANCHOR 3
MOVEMENT wrt DEEPEST ANCHOR (inches)
0.25
0.20
0.15
0.10
0.05
0.00
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800
ELAPSED TIME (days)
DAY 0: 05/06/88

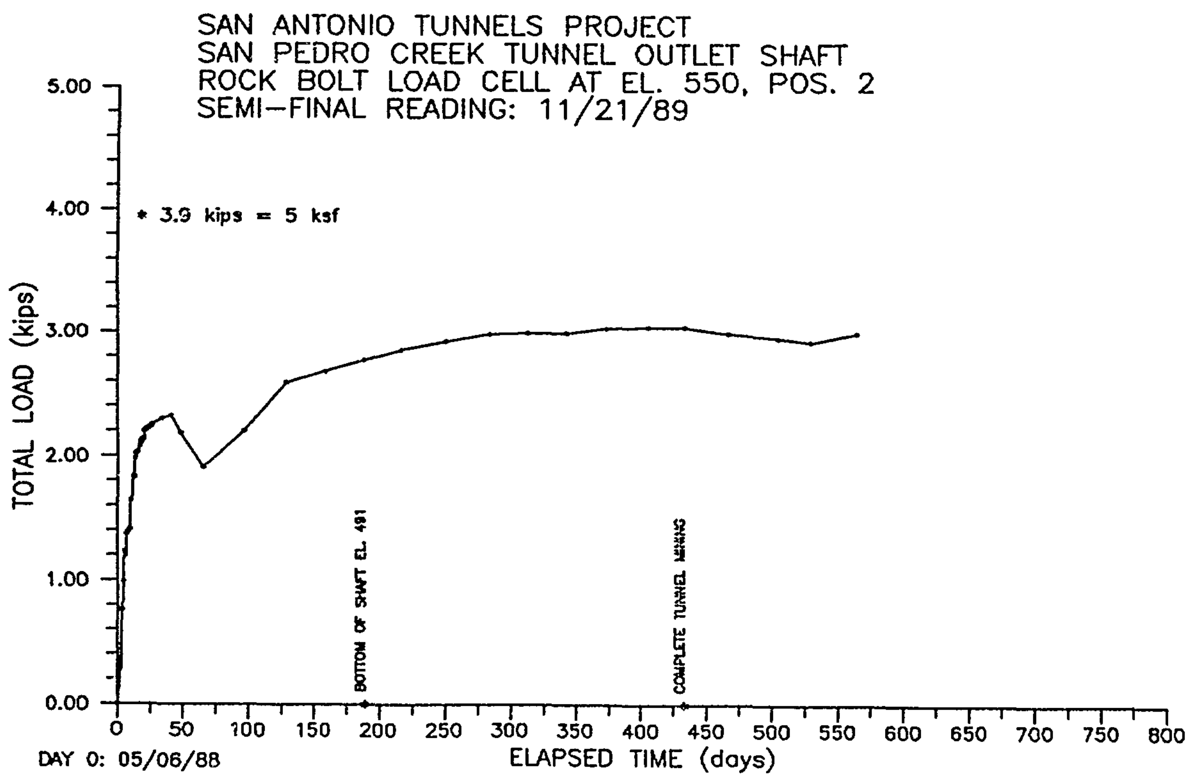

SAN ANTONIO TUNNELS PROJECT
SAN PEDRO CREEK TUNNEL OUTLET SHAFT
3-POS. BOREHOLE EXT. AT EL. 550, POS. B
SEMI-FINAL READING: 11/21/89
SURFACE to ANCHOR 3 (26 ft)
ANCHOR 1 (3 ft) to ANCHOR 3
ANCHOR 2 (11 ft) to ANCHOR 3
BOTTOM OF SHAFT EL 481
COMPLETE TUNNEL MINING
MOVEMENT wrt DEEPEST ANCHOR (inches)
0.25
0.20
0.15
0.10
0.05
0.00
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800
ELAPSED TIME (days)
DAY 0: 05/06/88



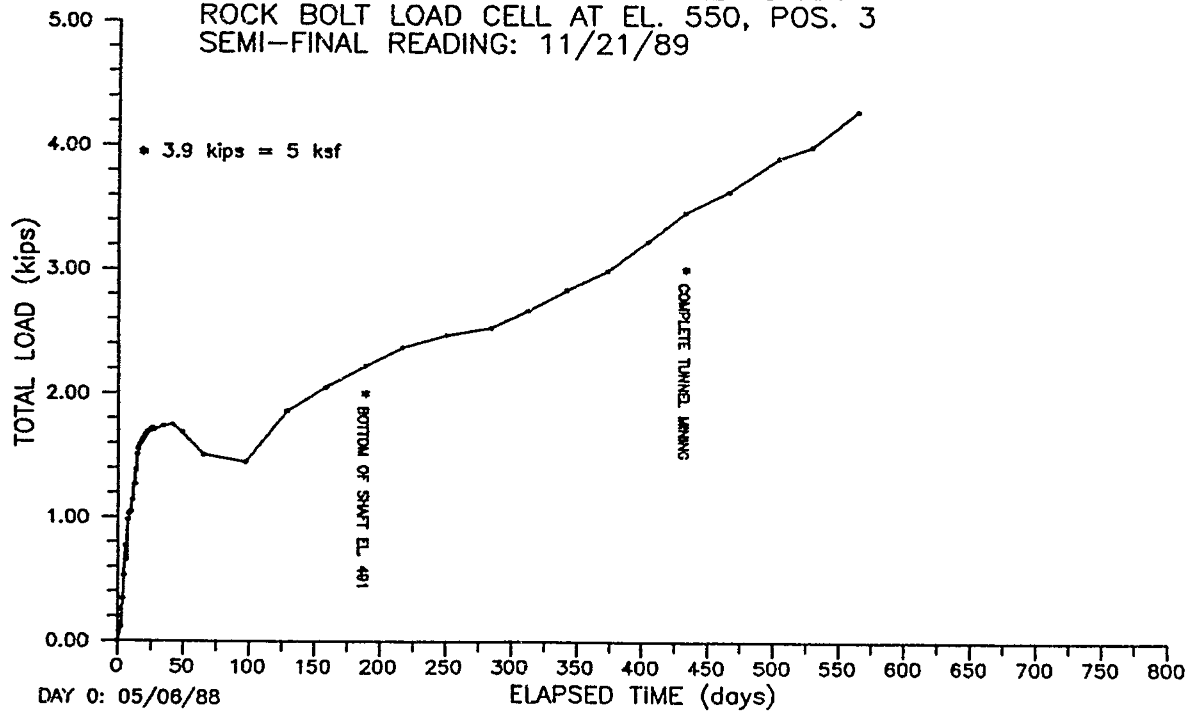
SAN ANTONIO TUNNELS PROJECT
SAN PEDRO CREEK TUNNEL OUTLET SHAFT
3-POS. BOREHOLE EXT. AT EL. 550, POS. C
SEMI-FINAL READING: 11/21/89
SURFACE to ANCHOR 3 (26 ft)
ANCHOR 1 (3 ft) to ANCHOR 3
ANCHOR 2 (11 ft) to ANCHOR 3
BOTTOM OF SHAFT EL. 481
COMPLETE TUNNEL MINING
MOVEMENT wrt DEEPEST ANCHOR (inches)
0.25
0.20
0.15
0.10
0.05
0.00
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800
ELAPSED TIME (days)
DAY 0: 05/06/88

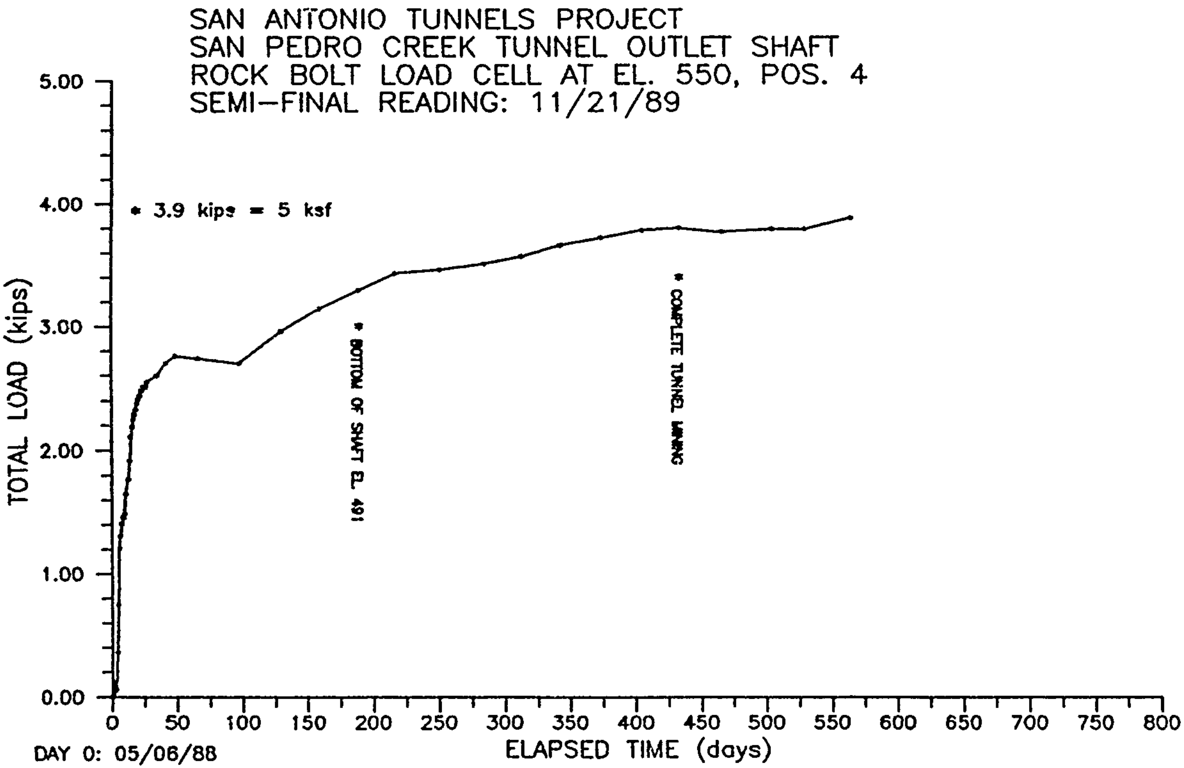

SAN ANTONIO TUNNELS PROJECT
SAN PEDRO CREEK TUNNEL OUTLET SHAFT
3-POS. BOREHOLE EXT. AT EL. 550, POS. D
SEMI-FINAL READING: 11/21/89
SURFACE to ANCHOR 3 (26 ft)
ANCHOR 1 (3 ft) to ANCHOR 3
ANCHOR 2 (11 ft) to ANCHOR 3
BOTTOM OF SHAFT EL. 481
COMPLETE TUNNEL MINING
MOVEMENT wrt DEEPEST ANCHOR (inches)
0.25
0.20
0.15
0.10
0.05
0.00
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800
ELAPSED TIME (days)
DAY 0: 05/08/88


SAN ANTONIO TUNNELS PROJECT
SAN PEDRO CREEK TUNNEL OUTLET SHAFT
ROCK BOLT LOAD CELL AT EL. 550, POS. 1
SEMI-FINAL READING: 11/21/89
* 3.9 kips = 5 ksf
LOAD CELL DISTURBED BY
CONSTRUCTION ACTIVITIES
BOTTOM OF SHAFT EL. 491
COMPLETE TUNNEL MINING
TOTAL LOAD (kips)
5.00
4.00
3.00
2.00
1.00
0.00
-1.00
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800
DAY 0: 05/06/88
ELAPSED TIME (days)


SAN ANTONIO TUNNELS PROJECT
SAN PEDRO CREEK TUNNEL OUTLET SHAFT
ROCK BOLT LOAD CELL AT EL. 550, POS. 2
SEMI-FINAL READING: 11/21/89
* 3.9 kips = 5 ksf
TOTAL LOAD (kips)
5.00
4.00
3.00
2.00
1.00
0.00
BOTTOM OF SHAFT EL. 491
COMPLETE TUNNEL MINING
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800
DAY 0: 05/06/88
ELAPSED TIME (days)

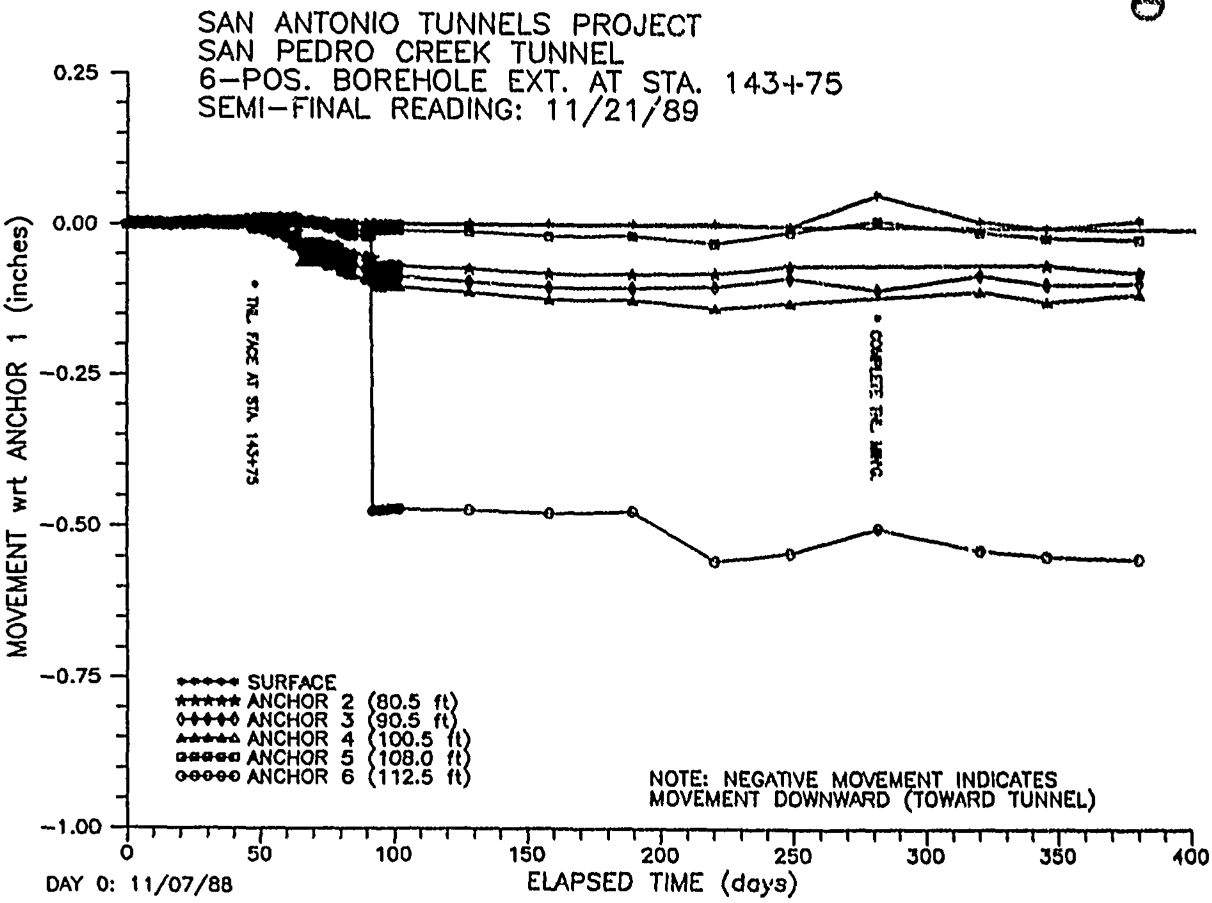
SAN ANTONIO TUNNELS PROJECT
SAN PEDRO CREEK TUNNEL OUTLET SHAFT
ROCK BOLT LOAD CELL AT EL. 550, POS. 3
SEMI–FINAL READING: 11/21/89

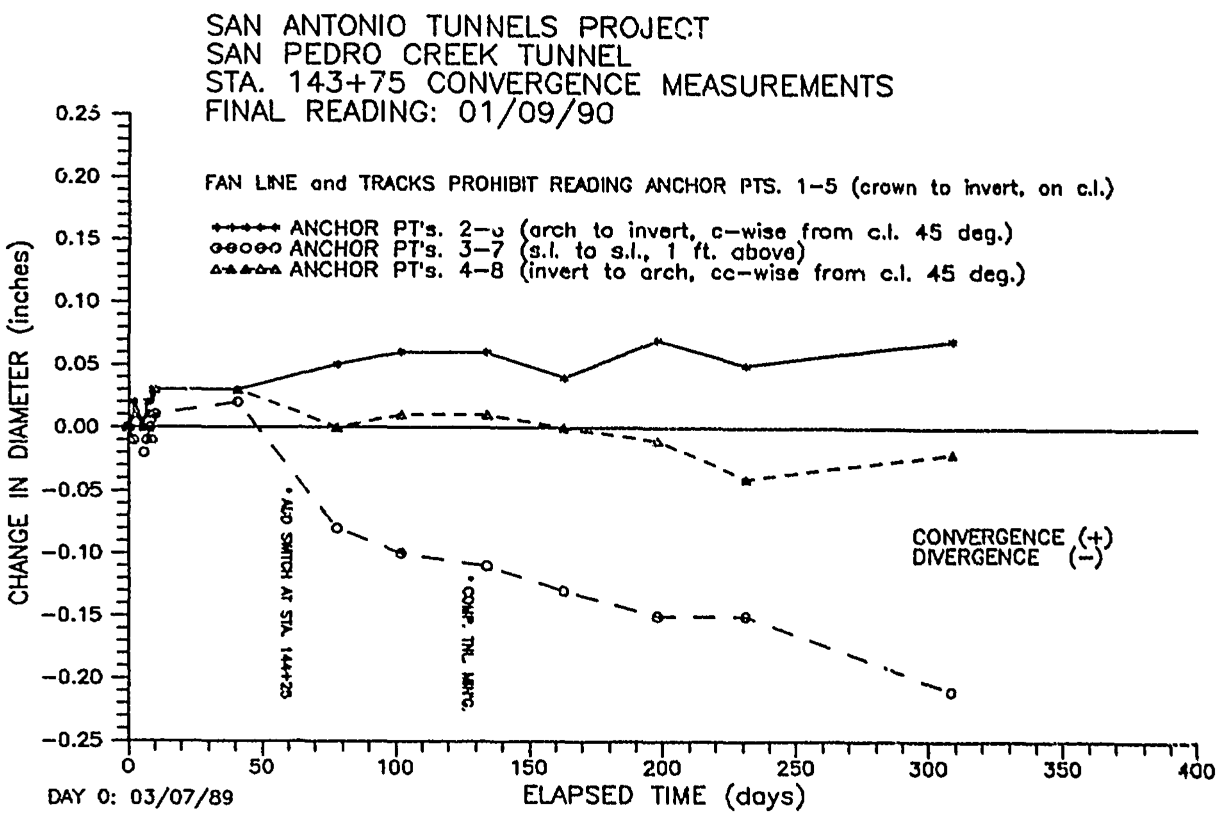




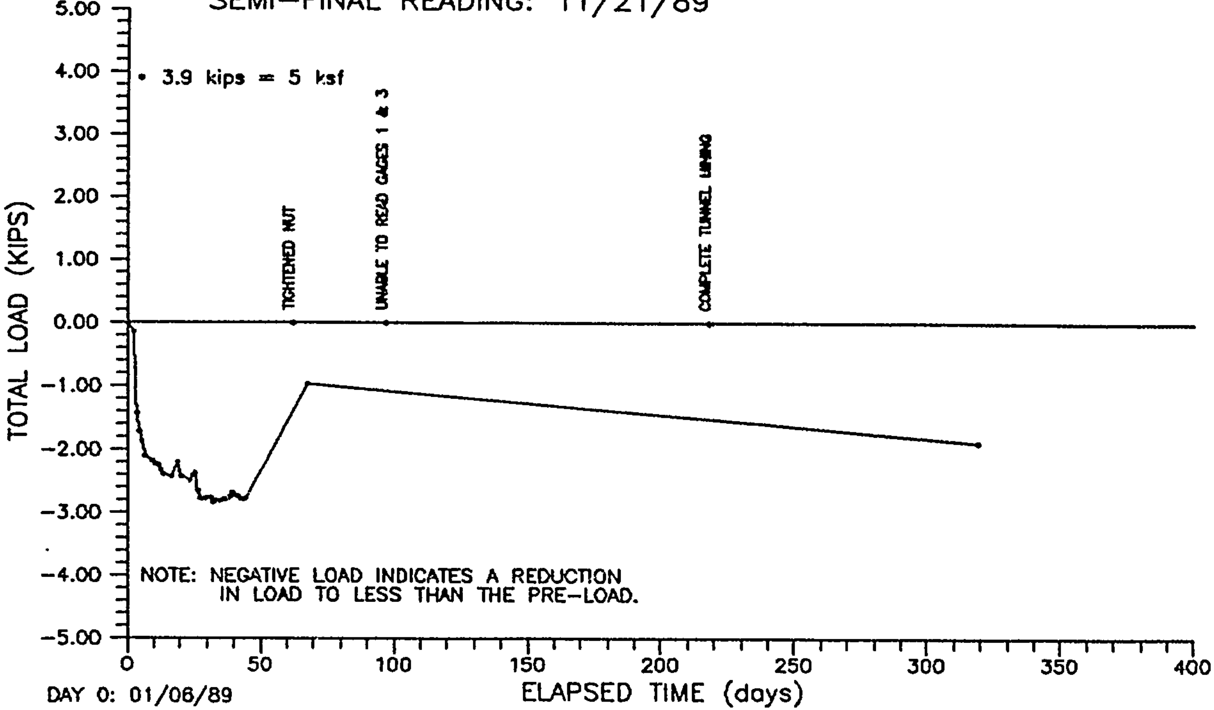
SAN ANTONIO TUNNELS PROJECT
SAN PEDRO CREEK TUNNEL OUTLET SHAFT
ROCK BOLT LOAD CELL AT EL. 550, POS. 4
SEMI-FINAL READING: 11/21/89
* 3.9 kips = 5 ksf
* BOTTOM OF SHAFT EL. 491
* COMPLETE TUNNEL MINING
TOTAL LOAD (kips)
5.00
4.00
3.00
2.00
1.00
0.00
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800
ELAPSED TIME (days)
DAY 0: 05/06/88

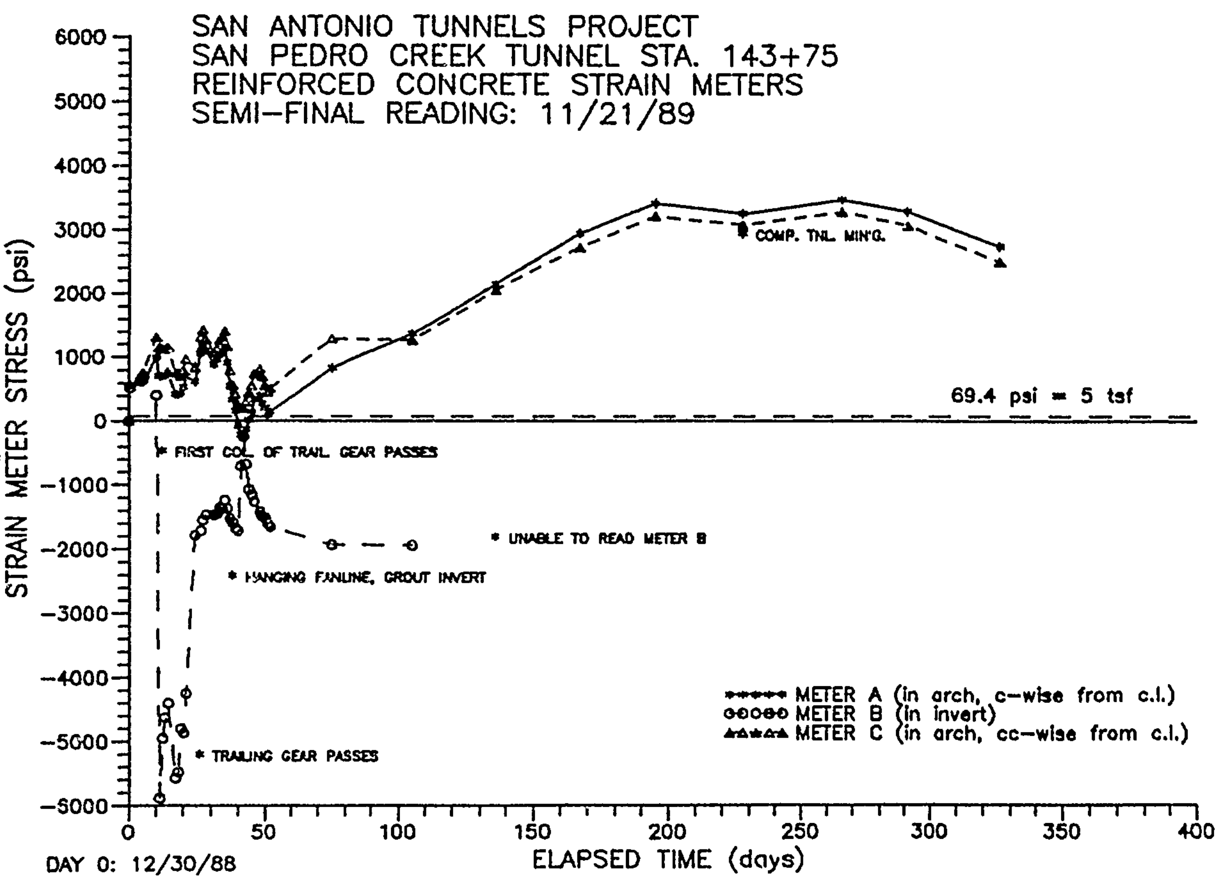
TUNNEL STATION 143+75

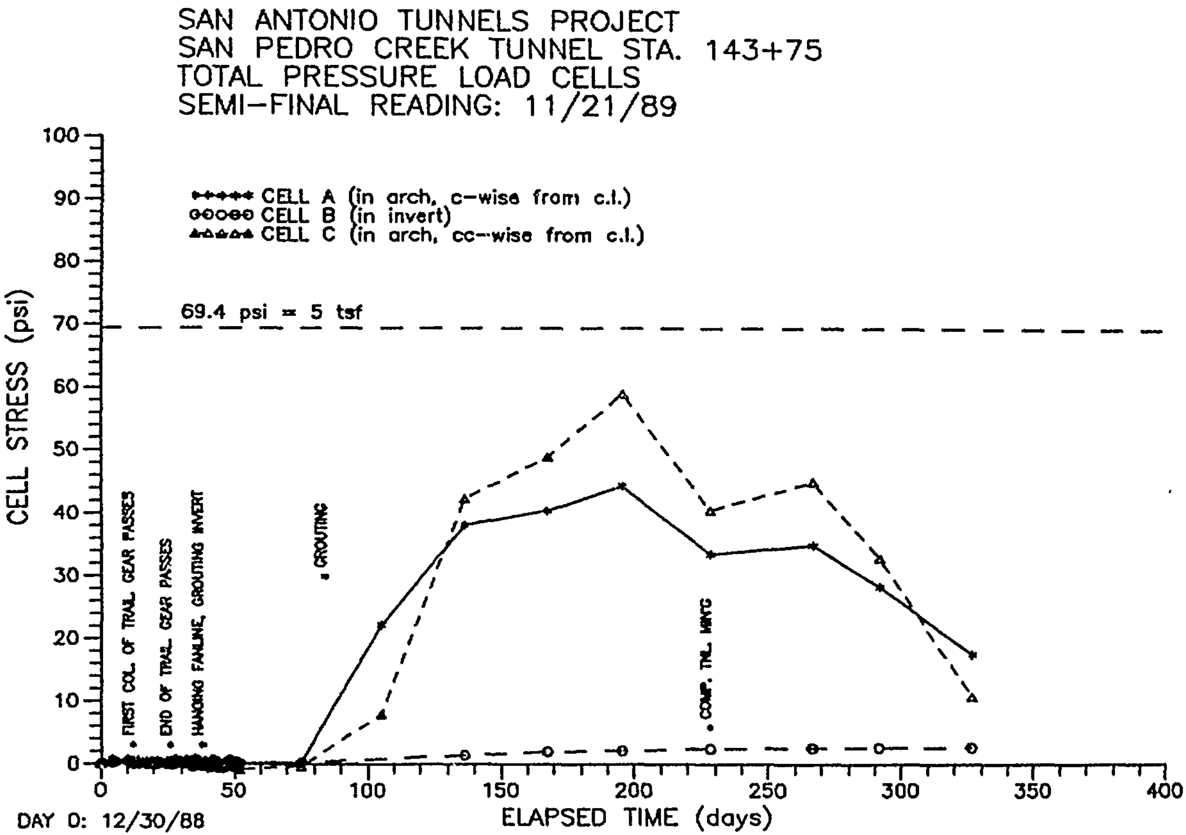

SAN ANTONIO TUNNELS PROJECT
SAN PEDRO CREEK TUNNEL
6-POS. BOREHOLE EXT. AT STA. 143+75
SEMI-FINAL READING: 11/21/89
MOVEMENT wrt ANCHOR 1 (inches)
0.25
0.00
-0.25
-0.50
-0.75
-1.00
• TNL. FACE AT STA. 143+75
• COMPLETE TNL. MNG.
SURFACE
ANCHOR 2 (80.5 ft)
ANCHOR 3 (90.5 ft)
ANCHOR 4 (100.5 ft)
ANCHOR 5 (108.0 ft)
ANCHOR 6 (112.5 ft)
NOTE: NEGATIVE MOVEMENT INDICATES
MOVEMENT DOWNWARD (TOWARD TUNNEL)
0
50
100
150
200
250
300
350
400
DAY 0: 11/07/88
ELAPSED TIME (days)


SAN ANTONIO TUNNELS PROJECT
SAN PEDRO CREEK TUNNEL
STA. 143+75 CONVERGENCE MEASUREMENTS
FINAL READING: 01/09/90
FAN LINE and TRACKS PROHIBIT READING ANCHOR PTS. 1-5 (crown to invert, on c.l.)
ANCHOR PT's. 2-6 (arch to invert, c-wise from c.l. 45 deg.)
ANCHOR PT's. 3-7 (s.l. to s.l., 1 ft. above)
ANCHOR PT's. 4-8 (invert to arch, cc-wise from c.l. 45 deg.)
CONVERGENCE (+)
DIVERGENCE (-)
ALO SWITCH AT STA. 144+25
COMP. TNL. MNG.
CHANGE IN DIAMETER (inches)
0.25
0.20
0.15
0.10
0.05
0.00
-0.05
-0.10
-0.15
-0.20
-0.25
0
50
100
150
200
250
300
350
400
ELAPSED TIME (days)
DAY 0: 03/07/89

SAN ANTONIO TUNNELS PROJECT
SAN PEDRO CREEK TUNNEL
ROCK BOLT LOAD CELL AT STA. 143+75
SEMI–FINAL READING: 11/21/89



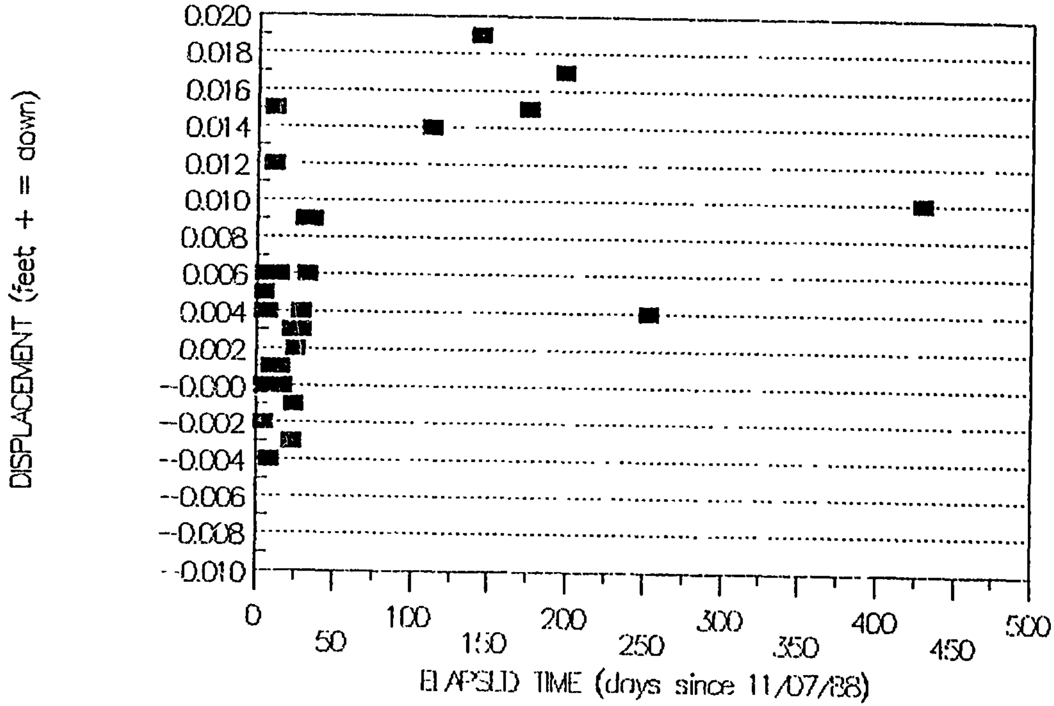

SAN ANTONIO TUNNELS PROJECT
SAN PEDRO CREEK TUNNEL STA. 143+75
REINFORCED CONCRETE STRAIN METERS
SEMI-FINAL READING: 11/21/89
STRAIN METER STRESS (psi)
6000
5000
4000
3000
2000
1000
0
-1000
-2000
-3000
-4000
-5000
-6000
0
50
100
150
200
250
300
350
400
ELAPSED TIME (days)
DAY 0: 12/30/88
69.4 psi = 5 tsf
* COMP. TNL. MIN'G.
* FIRST COL. OF TRAIL. GEAR PASSES
* UNABLE TO READ METER B
* HANGING FANLINE, GROUT INVERT
* TRAILING GEAR PASSES
METER A (in arch, c-wise from c.l.)
METER B (in invert)
METER C (in arch, cc-wise from c.l.)



SAN ANTONIO TUNNELS PROJECT
SAN PEDRO CREEK TUNNEL STA. 143+75
TOTAL PRESSURE LOAD CELLS
SEMI-FINAL READING: 11/21/89
CELL A (in arch, c-wise from c.l.)
CELL B (in invert)
CELL C (in arch, cc-wise from c.l.)
69.4 psi = 5 tsf
CELL STRESS (psi)
FIRST COL. OF TRAIL. GEAR PASSES
END OF TRAIL. GEAR PASSES
HANGING FANLINE, GROUTING INVERT
GROUTING
COMP. TNL. MNTG
DAY 0: 12/30/88
ELAPSED TIME (days)

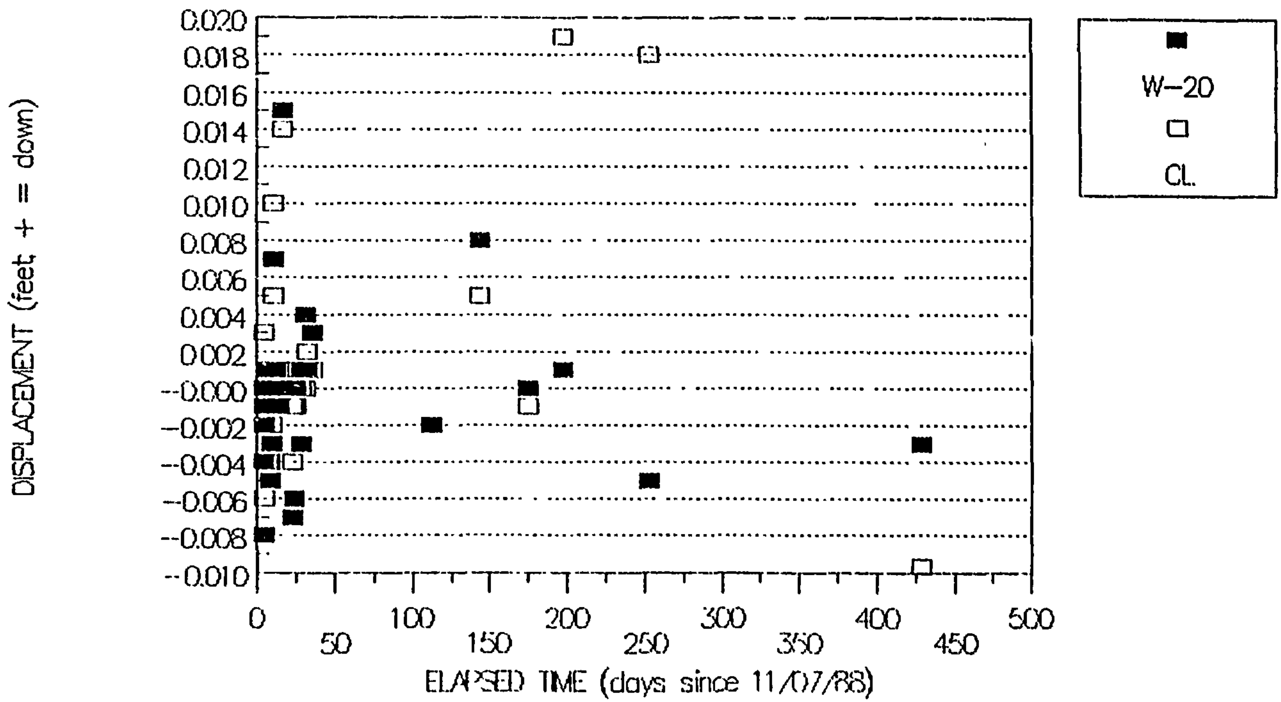
SAN PEDRO CREEK TUNNEL

DISPLACEMENT MARKER—STA. 143+00 CL



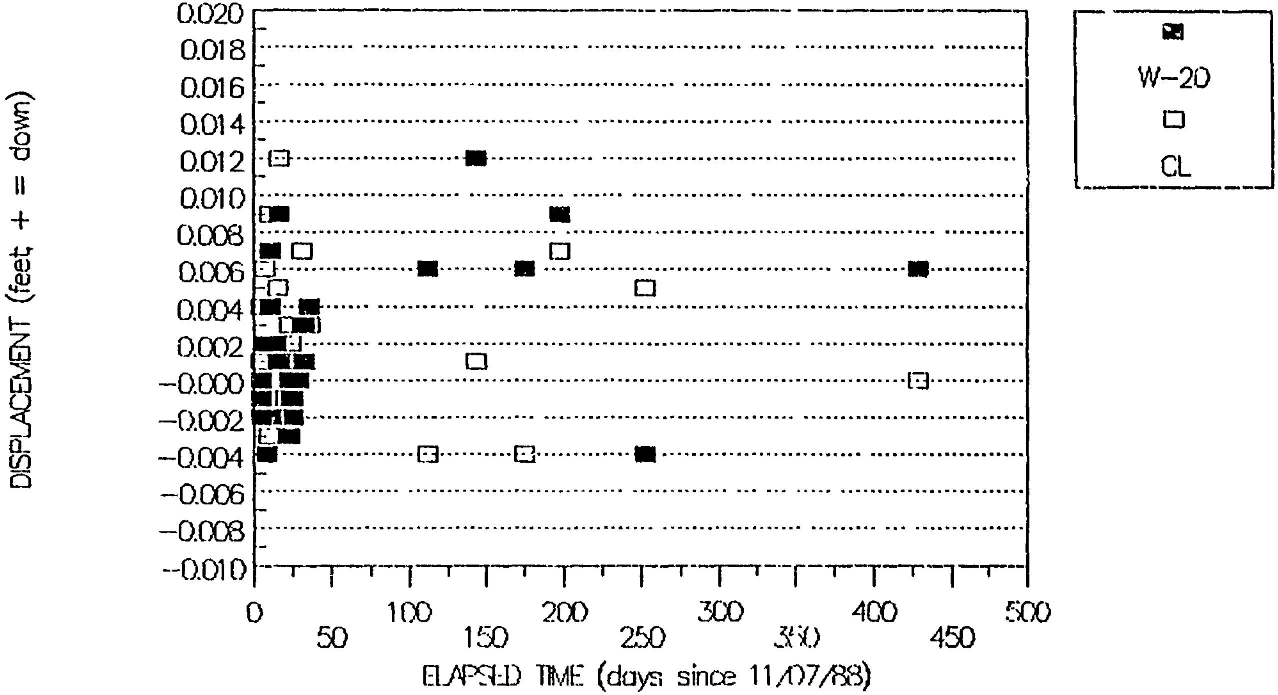
SAN PEDRO CREEK TUNNEL

DISPLACEMENT MARKERS--STA. 143+05.5



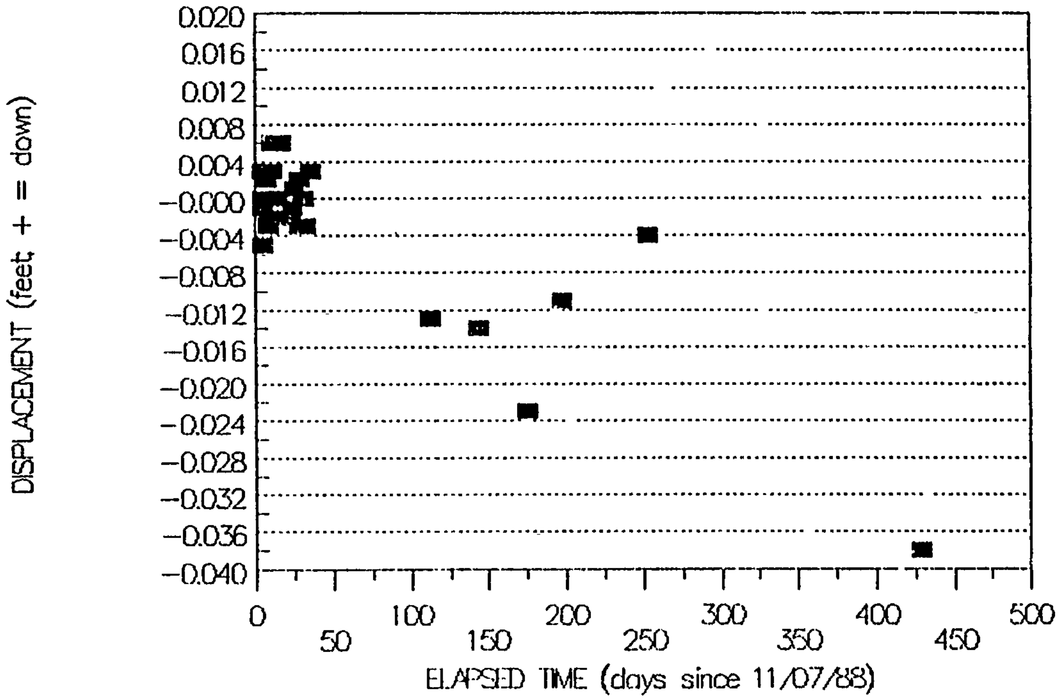
SAN PEDRO CREEK TUNNEL

DISPLACEMENT MARKERS–STA. 143+40



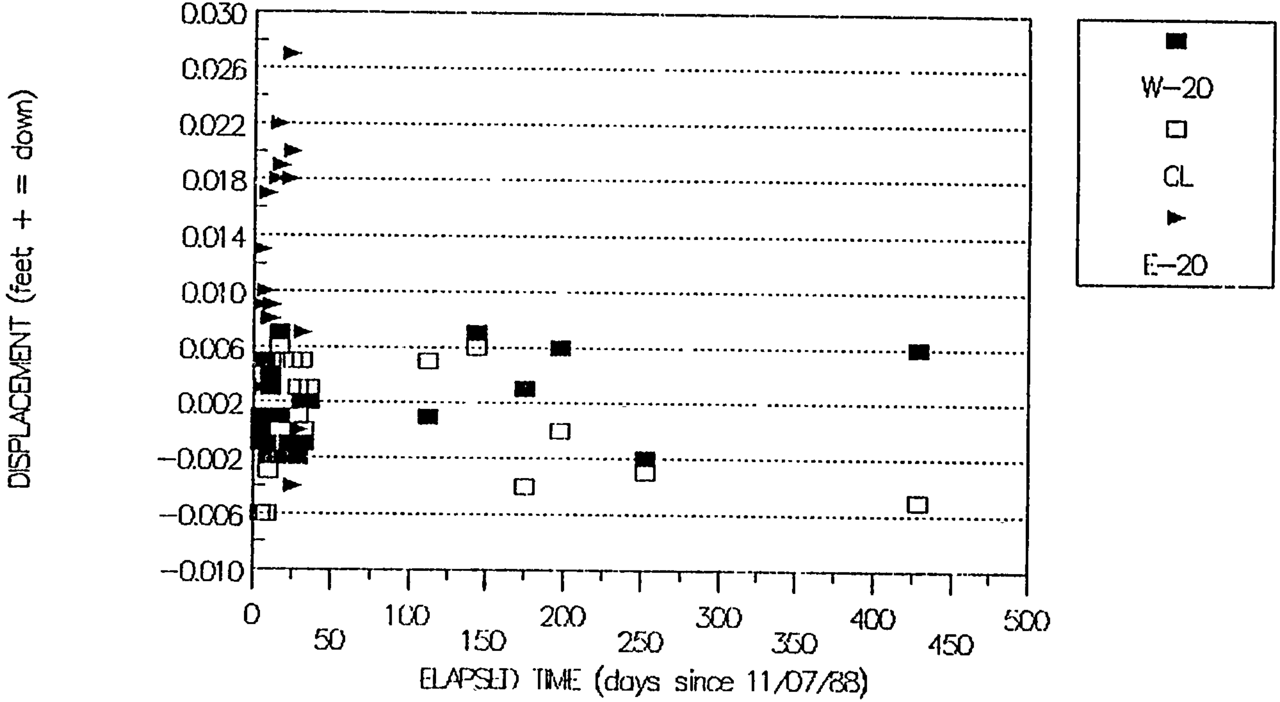
SAN PEDRO CREEK TUNNEL

DISPLACEMENT MARKER–STA. 143+75 CL



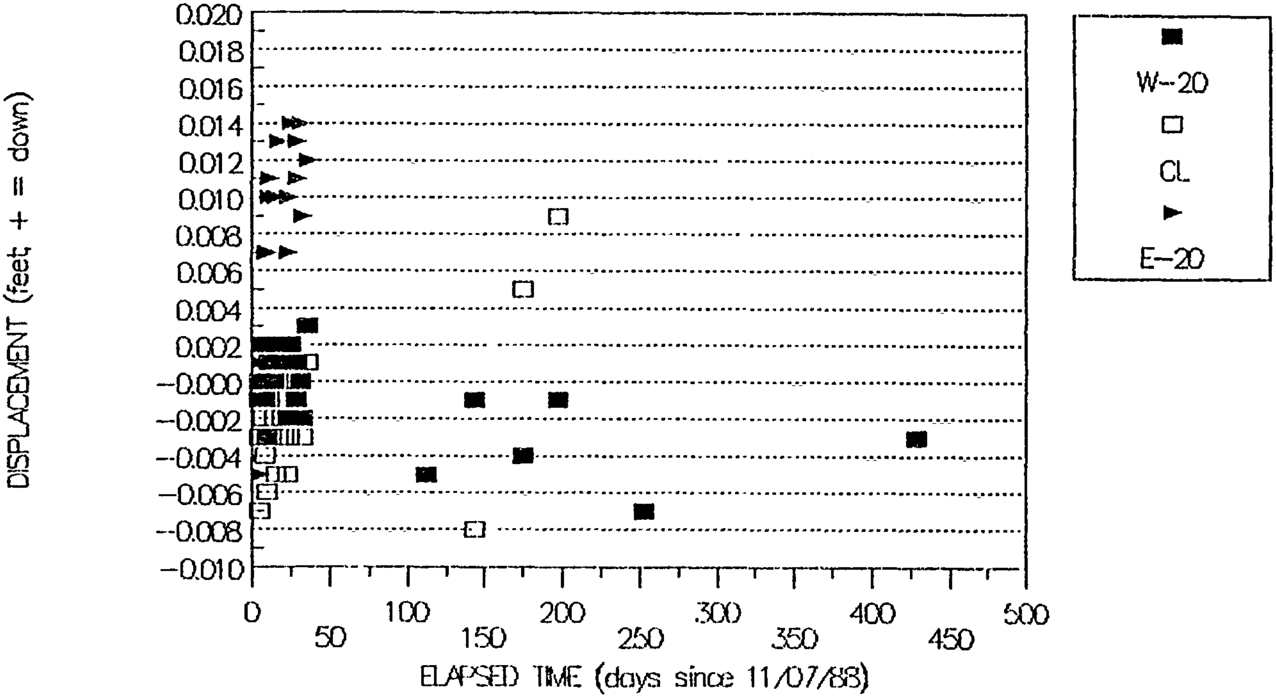
SAN PEDRO CREEK TUNNEL

DISPLACEMENT MARKERS—STA. 143+80



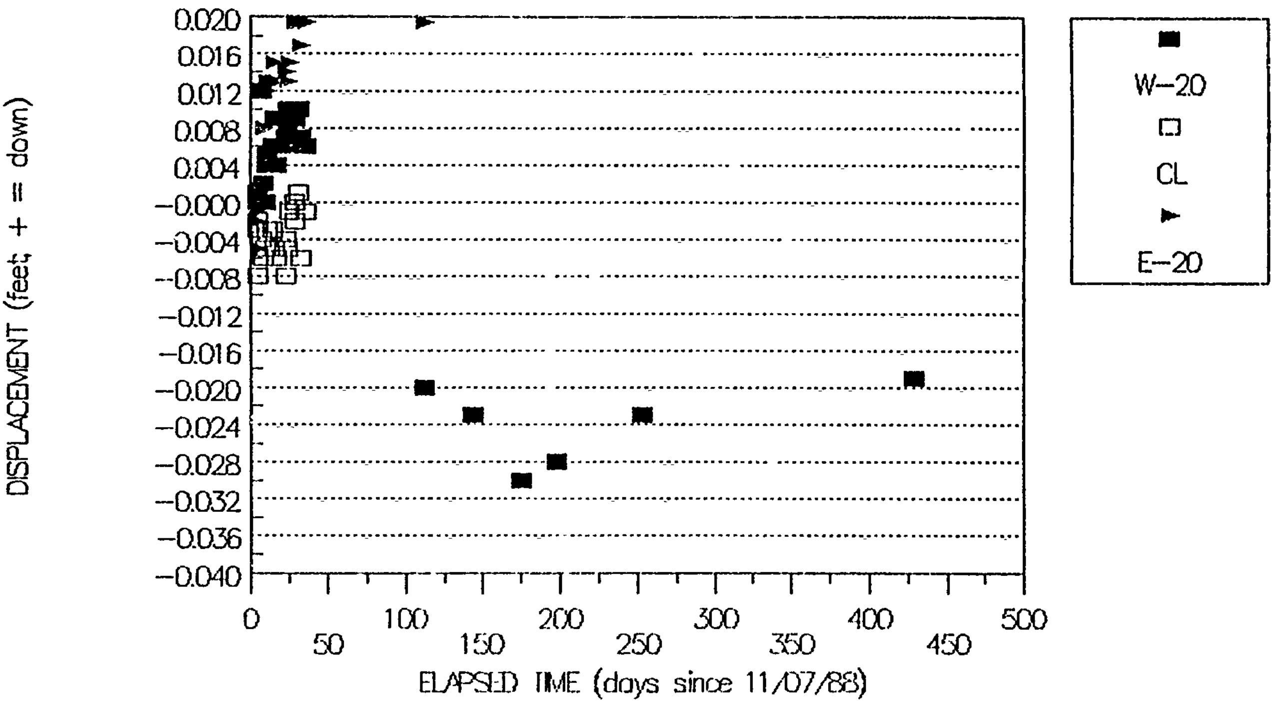
SAN PEDRO CREEK TUNNEL

DISPLACEMENT MARKERS–STA. 144+20



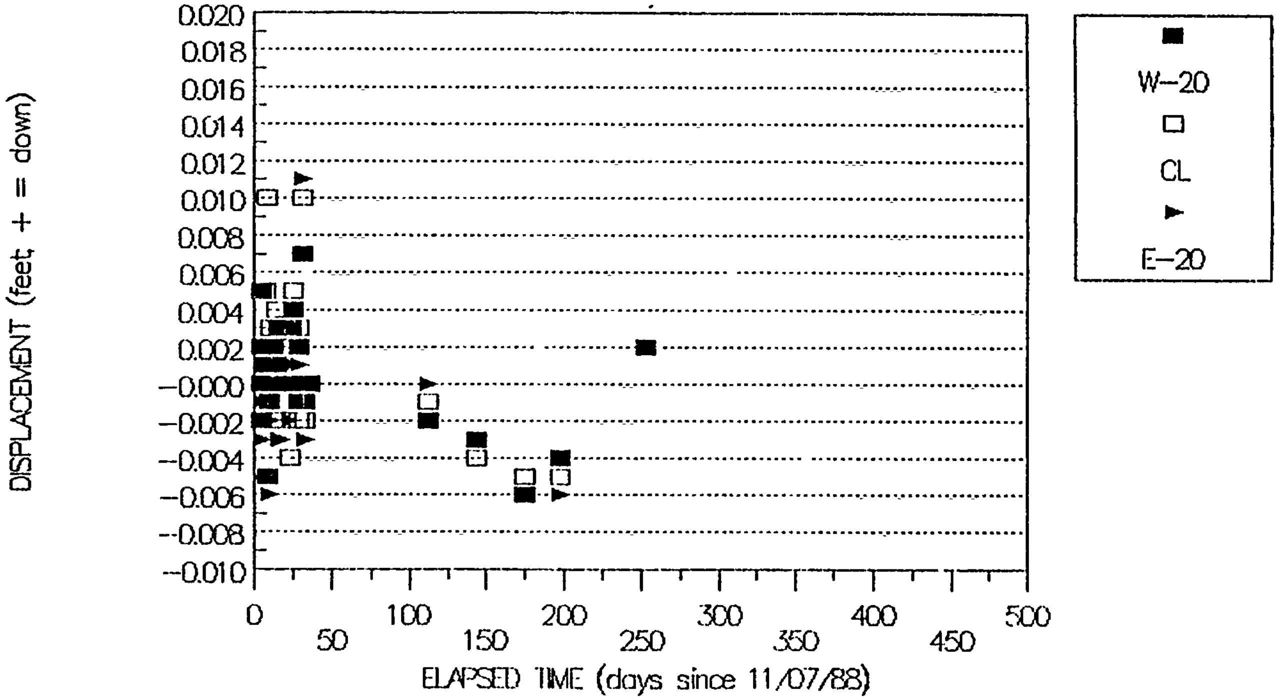
SAN PEDRO CREEK TUNNEL

DISPLACEMENT MARKERS–STA. 144+60



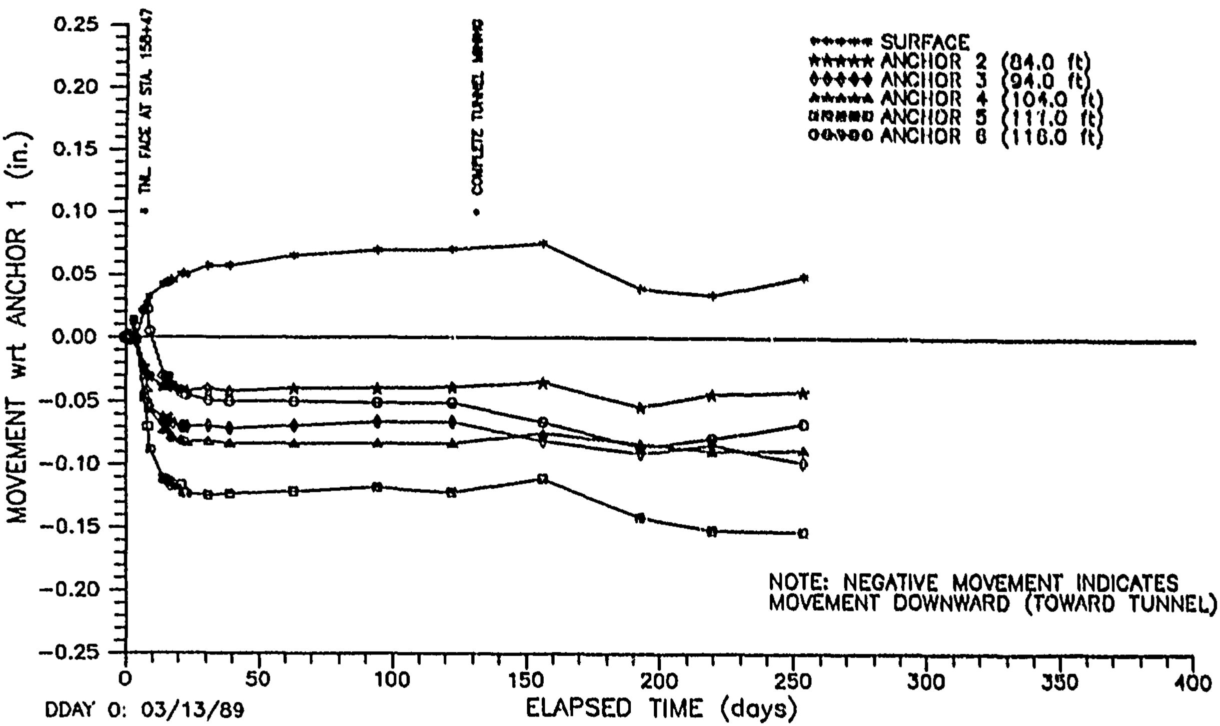
SAN PEDRO CREEK TUNNEL

DISPLACEMENT MARKERS--STA. 145+00

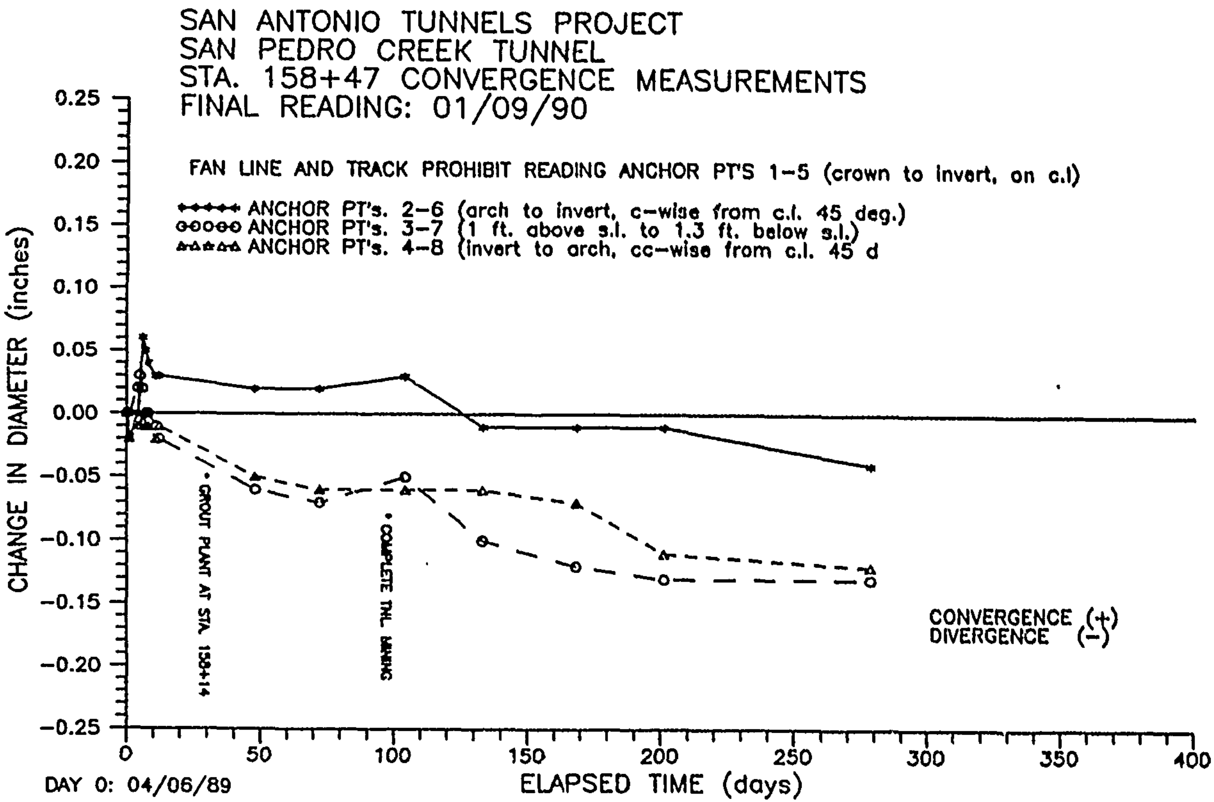


TUNNEL STATION 132+47

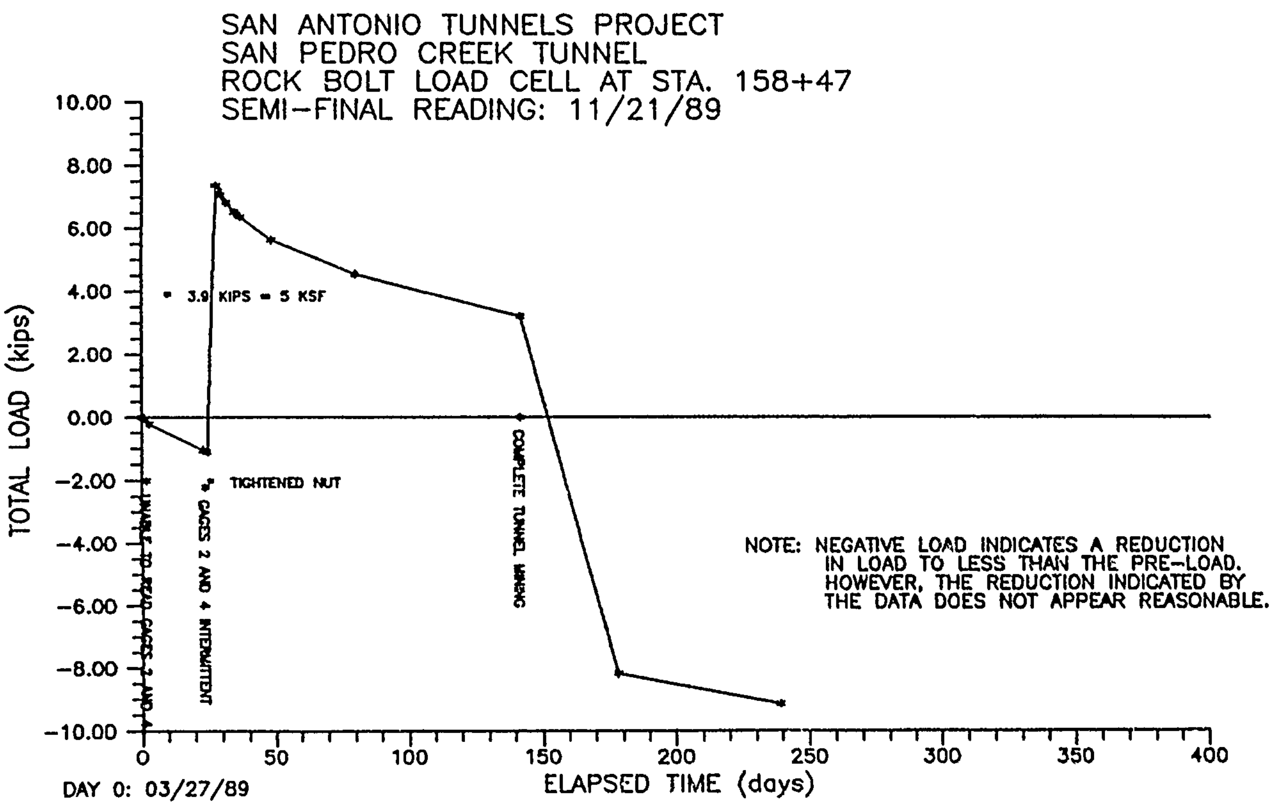
SAN ANTONIO TUNNELS PROJECT
SAN PEDRO CREEK TUNNEL
6-POS. BOREHOLE EXT. AT STA. 158+47
SEMI-FINAL READING: 11/21/89

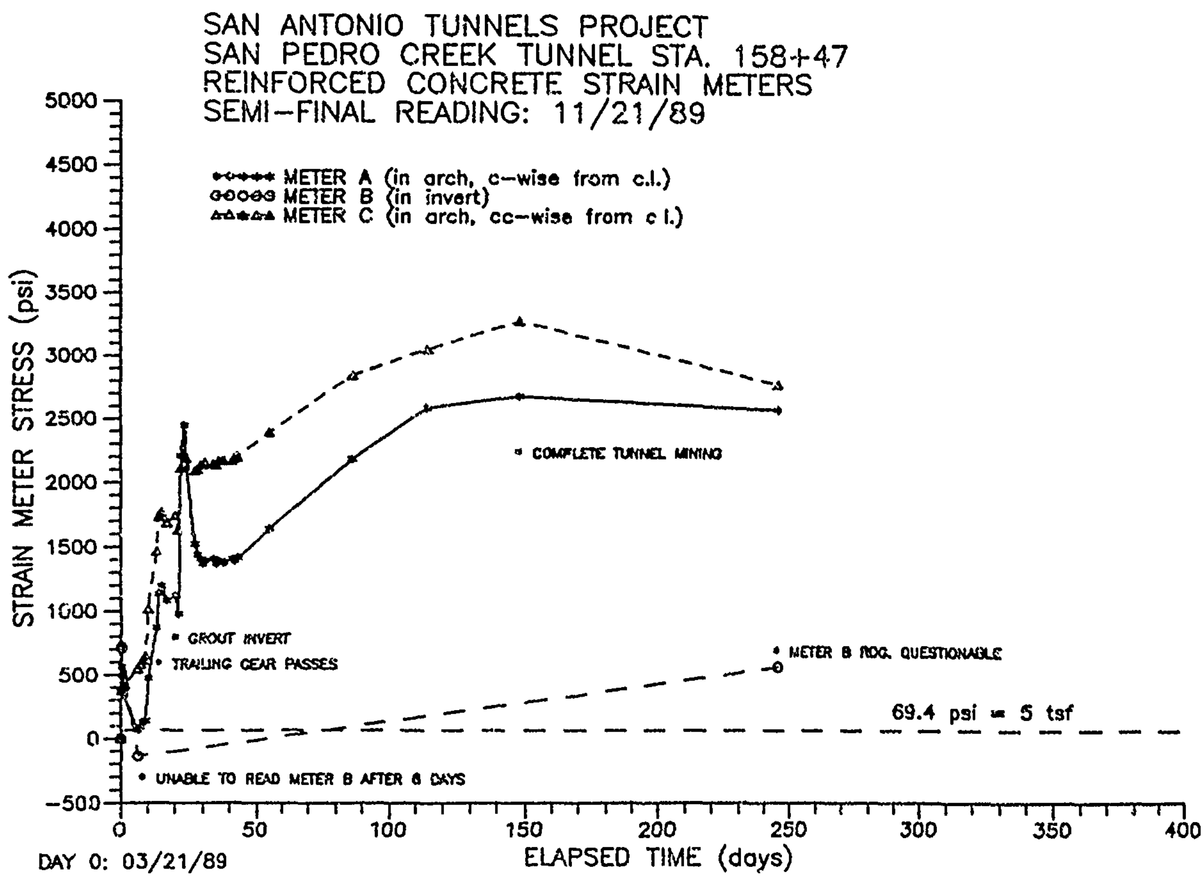


D

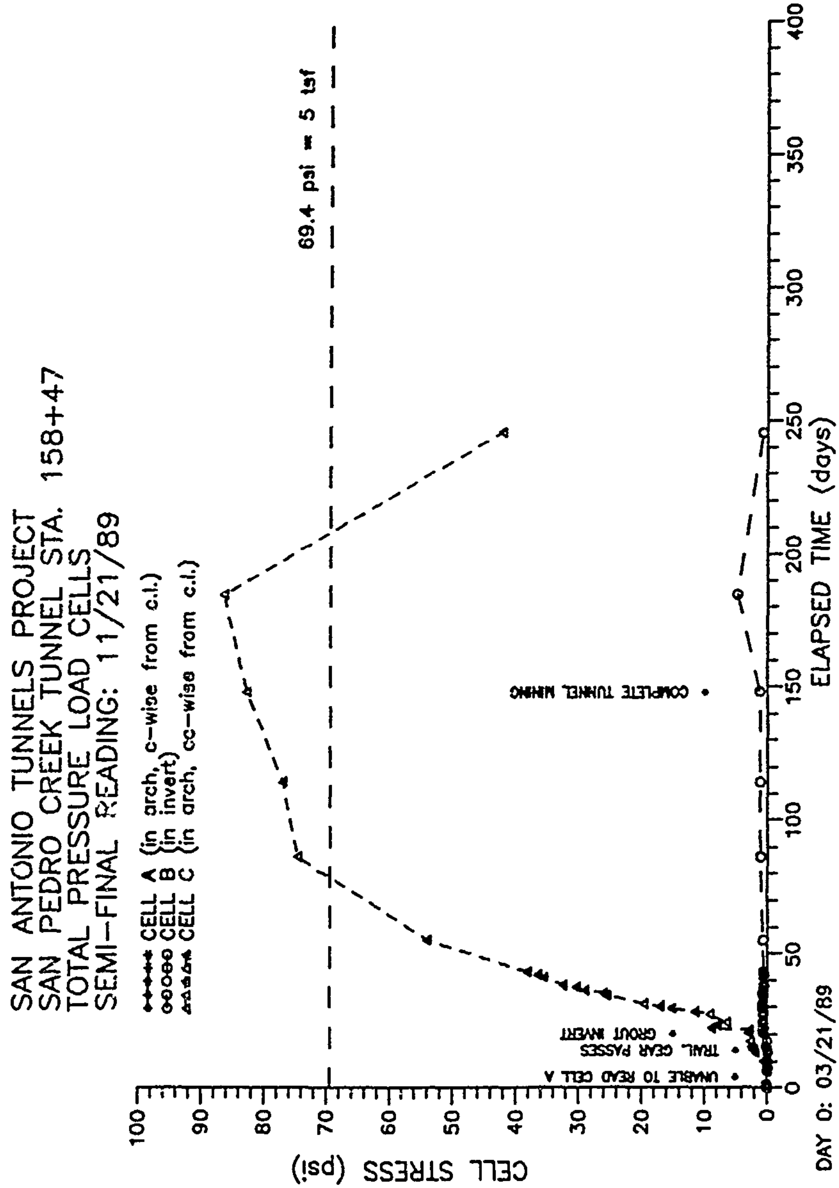


SAN ANTONIO TUNNELS PROJECT
SAN PEDRO CREEK TUNNEL
STA. 158+47 CONVERGENCE MEASUREMENTS
FINAL READING: 01/09/90
FAN LINE AND TRACK PROHIBIT READING ANCHOR PT'S 1-5 (crown to invert, on c.l)
ANCHOR PT's. 2-6 (arch to invert, c-wise from c.l. 45 deg.)
ANCHOR PT's. 3-7 (1 ft. above s.l. to 1.3 ft. below s.l.)
ANCHOR PT's. 4-8 (invert to arch, cc-wise from c.l. 45 d
CHANGE IN DIAMETER (inches)
0.25
0.20
0.15
0.10
0.05
0.00
-0.05
-0.10
-0.15
-0.20
-0.25
• GROUT PLANT AT STA. 158+14
• COMPLETE TNL. MINING
CONVERGENCE (+)
DIVERGENCE (-)
0
50
100
150
200
250
300
350
400
DAY 0: 04/06/89
ELAPSED TIME (days)


SAN ANTONIO TUNNELS PROJECT
SAN PEDRO CREEK TUNNEL
ROCK BOLT LOAD CELL AT STA. 158+47
SEMI-FINAL READING: 11/21/89
TOTAL LOAD (kips)
10.00
8.00
6.00
4.00
2.00
0.00
-2.00
-4.00
-6.00
-8.00
-10.00
* 3.9 KIPS = 5 KSF
* UNABLE TO READ GAGES 2 AND 4
* GAGES 2 AND 4 INTERMITTENT
* TIGHTENED NUT
COMPLETE TUNNEL MINING
NOTE: NEGATIVE LOAD INDICATES A REDUCTION IN LOAD TO LESS THAN THE PRE-LOAD. HOWEVER, THE REDUCTION INDICATED BY THE DATA DOES NOT APPEAR REASONABLE.
0
50
100
150
200
250
300
350
400
ELAPSED TIME (days)
DAY 0: 03/27/89



SAN ANTONIO TUNNELS PROJECT
SAN PEDRO CREEK TUNNEL STA. 158+47
REINFORCED CONCRETE STRAIN METERS
SEMI-FINAL READING: 11/21/89
METER A (in arch, c-wise from c.l.)
METER B (in invert)
METER C (in arch, cc-wise from c l.)
COMPLETE TUNNEL MINING
GROUT INVERT
TRAILING GEAR PASSES
METER B RDG. QUESTIONABLE
69.4 psi = 5 tsf
UNABLE TO READ METER B AFTER 6 DAYS
STRAIN METER STRESS (psi)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
-500
0
50
100
150
200
250
300
350
400
ELAPSED TIME (days)
DAY 0: 03/21/89


SAN ANTONIO TUNNELS PROJECT
SAN PEDRO CREEK TUNNEL STA. 158+47
TOTAL PRESSURE LOAD CELLS
SEMI-FINAL READING: 11/21/89
CELL A (in arch, c-wise from c.l.)
CELL B (in invert)
CELL C (in arch, cc-wise from c.l.)
69.4 psi = 5 tsf
UNABLE TO READ CELL A
TRAIL GEAR PASSES
GROUT INVERT
COMPLETE TUNNEL MINING
CELL STRESS (psi)
ELAPSED TIME (days)
DAY 0: 03/21/89
0
10
20
30
40
50
60
70
80
90
100
0
50
100
150
200
250
300
350
400